

**OCTOBER 1996 FLOOD
REGIONAL ANALYSIS
MASSACHUSETTS AND NEW HAMPSHIRE**

PREPARED FOR:

**FEDERAL EMERGENCY MANAGEMENT AGENCY
REGION 1
BOSTON, MASSACHUSETTS**

PREPARED BY:

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**US Army Corps
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OCTOBER 1996 FLOOD
REGIONAL ANALYSIS
MASSACHUSETTS AND NEW HAMPSHIRE

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**October 1996 Flood
Regional Analysis
Massachusetts and New Hampshire**

1. GENERAL

During the 20th and 21st of October 1996, a steady and intense rainstorm occurred in eastern Massachusetts, New Hampshire, and southeastern Maine, resulting in high river stages and extensive flooding throughout this area. Rainfall totals were most significant in northeastern Massachusetts, coastal New Hampshire, and southeastern Maine. As a result of this flooding, New England District has identified known high water marks near selected rivers in an effort to characterize this flood event. These high water marks were used as an aid in determining the return frequency of this runoff event. This report is being prepared for FEMA as a part of Mission Assignment under the declaration FEMA-1142-DR-Massachusetts (included as Appendix A). The report presents the results of studies and investigations, including sections on storm rainfall totals and their corresponding frequencies, peak discharges and their frequencies, as well as comparisons to existing Flood Insurance Studies for the areas where high water marks were obtained. The detailed sheets locating and presenting elevations of high water marks as well as GIS component were presented in report titled "High Water Mark Report, Storm Event of October 20-21, 1996."

2. PURPOSE

The purpose of this effort is to determine the return frequency of the event at selected rivers. This information will be used to provide an indication of the severity of the event in relation to other historic flooding events. The determination of the return frequency included the following tasks: evaluate rainfall totals at key stations throughout Massachusetts and New Hampshire with consideration of National Weather Service published rainfall frequency data; compute discharge frequencies at pertinent gaging stations throughout the region in an effort to determine the return frequency of the runoff event; and, analyze surveyed high water mark data, flood profiles, etc, and estimate return frequency for areas with no gaged flow data. This was done to provide FEMA with an historical perspective for the peak elevations, locations of high water, and frequency of flooding. This will allow FEMA mitigation employees and community officials to locate future development above potential flood levels. The benefit/cost of mitigation projects can also be calculated.

3. STUDY AREA

As stated earlier, high water marks were gathered by NED along seven rivers in northeastern Massachusetts and coastal New Hampshire, as a result of the October 1996 flooding. The selected rivers where high water marks were gathered are as follows:

Shawsheen River (Lawrence, Andover, Tewksbury, Billerica, and Bedford, MA)
Spicket River (Methuen and Lawrence, MA and Salem, NH)
Aberjona River (Winchester and Woburn, MA)
Alewife Brook (Arlington and Cambridge, MA)
Neponset River (Milton, Canton, and Norwood, MA)
Lamprey River (Epping, NH)
Little River (North Hampton, NH)

Plate 1 shows the locations of each of the above rivers watersheds. We note that some of these rivers were selected due to ongoing Corps of Engineer studies.

4. STORM OF 20 AND 21 OCTOBER 1996

a. General

The October 20-21, 1996 storm event produced rainfall totals ranging from 6 inches in southeastern Massachusetts to 13 inches in northeastern Massachusetts and coastal New Hampshire. The steady rain began on 20 October and lasted until midday on 21 October and fell primarily in eastern Massachusetts, New Hampshire, and Maine. Plate 2 presents locations of rain gage stations and their corresponding October 1996 storm rainfall totals (in inches), as reported and/or published by the National Weather Service (NWS). As can be seen, hardest hit was northeastern Massachusetts and coastal New Hampshire, where 10-13 inches of rainfall was experienced in about 36 hours. The highest total rainfall in the study area was recorded at Newburyport, MA, where 13.03 inches of rainfall was recorded. Lesser amounts of rainfall were recorded to the south of Boston and central and western Massachusetts. Also receiving significant rainfall was Portland, ME, where up to 19 inches of rain fell in the surrounding area. The Portland gage, however, only recorded 12.55 inches for the event showing the highly variable nature of this event with totals ranging widely within a relatively small geographic distances. An isohyetal map of the study area for this event is shown on Plate 3. This plate was developed by combination of plotted rainfall totals and with consideration of isohyetal maps developed by the National Weather Services' Maine and Massachusetts offices.

b. Rainfall Frequencies

To get an idea of the percent chance of occurrence of the October rainfall event, rainfall frequency curves were developed from U.S. Weather Bureau Technical Paper 40 (TP40) and U.S. Weather Bureau Technical Paper 49 (TP49) data, for two representative areas in the study region. One area is representative of the central coastal Massachusetts area (Shawsheen, Aberjona, Alewife, and Neponset Watersheds), and the other is representative of northeastern Massachusetts and coastal New Hampshire (Spicket, Lamprey, and Little River watersheds). Peak storm rainfall frequency-duration data, as reported by TP-40&49, are summarized in Table 1 for the two representative areas. The 100-year 1-day duration rainfall is 6-7 inches and the 2-day duration rainfall is 8-9 inches, for the two regional areas. Recorded rainfall totals and durations of the event were compared to TP40 and TP49 rainfall data.

TABLE 1

U.S. Weather Bureau
TP40 and TP49
Rainfall Frequency-Duration Data

**Northern Coastal Massachusetts
and
Coastal New Hampshire**

Rainfall in Inches

Frequency	Duration				
	6-Hour	12-Hour	1-Day	2-Day	4-Day
5-Year	2.7	3.3	3.9	4.6	5.5
10-Year	3.2	3.8	4.5	5.5	6.2
25-Year	3.6	4.4	5.2	6.5	7.3
50-Year	4.1	4.9	5.7	7.5	8.4
100-Year	4.6	5.5	6.5	8.0	9.4

Central Coastal Massachusetts

Rainfall in Inches

Frequency	Duration				
	6-Hour	12-Hour	1-Day	2-Day	4-Day
5-Year	2.8	3.4	4.1	5.0	5.7
10-Year	3.3	4.0	4.7	5.9	6.9
25-Year	3.8	4.6	5.5	6.9	7.7
50-Year	4.3	5.2	6.1	7.9	8.8
100-Year	4.7	5.8	6.8	8.8	9.7

The storm duration was generally about 36 hours for most of the region. A few gages recorded storm durations varying from 24 hours to about 40 hours. Plate 4 presents mass rainfall curves for the Boston, Blue Hill, Reading and Salem, MA gages, illustrating the distribution of rainfall over time based on hourly recordings. As can be seen, recorded rainfall at Salem, MA, produced a storm total of about 10 inches in 36 hours, with over 8 inches falling in a 24 hour period. Rainfall at the Boston gage resulted in a storm total of 7.9 inches over a 34 hour period, with a maximum one-day total of about 6.6 inches. Maximum 6- and 12-hour duration rainfall amounts were not as significant as one-day and storm total amounts. For gages with daily totals only, storm durations were assumed to be approximately 36 hours (1.5 days), based on other durations in the area.

Based on a comparison of the recorded rainfall amounts and durations with the TP-40/49 values, the majority of northeastern Massachusetts, and coastal New Hampshire received rainfall in excess of a 100-year (1 percent chance) event. A 100-year event is one where the event has a 1 in 100 chance of occurring in any given year. The recurrence intervals presented are in terms of years. Plates 5 and 6 present rainfall frequency-duration curves for the two representative areas along with the recorded October 1996 rainfall totals for gages in and around each of the selected watersheds. The Spicket, Shawsheen, Lamprey, Little, Aberjona, and Alewife watersheds all received 1 percent chance rainfall or greater, along with the lower Neponset River watershed. Only the upper watershed of the Neponset River received rainfall less than a 100-year event. Based on the representative gages for the Neponset River, the upper portion of its watershed received 20- to 50-year rainfall. At the Boston gage this event was a 100-year event based on totals and durations. Plate 7 shows the approximate area that received 1% chance of occurrence, or greater, rainfall amounts.

c. Comparison With Past Rainfall Events

With most of the study area receiving rainfall equal to or greater than 1 percent chance (100-year) rainfall, a comparison to past significant storm events was made to get an historic indication as to the severity of this rainfall event. Three past events were analyzed, the March/April 1987, the January 1979, and August 1955. Each of the three resulted in significant runoff in differing portions of the study area. For instance, the August 1955 was the most significant event to occur in the Neponset watershed, however, was not nearly as significant in areas to the north. Total rainfall for this storm varied from 2-15 inches through the study area. The March 1987 event was the largest event to occur in northeastern Massachusetts and coastal New Hampshire, and the January 1979 event produced the largest flooding on the Aberjona and Shawsheen Rivers, prior to this event. It should be noted that there were differing antecedent conditions with each storm. Table 2 lists storm rainfall totals for each event, for differing areas of the region.

TABLE 2
Comparison of Past Storm Events Rainfall Totals

Region	Past Storm Events Rainfall Totals (Inches)		
	March/April 1987	January 1979	August 1955
Lamprey, Little and Spicket Watersheds	8-11	5	2-5
Shawsheen, Aberjona and Alewife Watersheds	9-12	7	9-13
Neponset Watershed	9	5	13-16
Storm Duration	8 days	6 days	4 days

The March/April 1987 event was the result of two periods of rainfall plus accompanying snowmelt. A total of 8-12 inches of rain fell over the region from 31 March - 8 April, with some areas receiving up to 8 inches of rain during a 4-day period. Past Corps of Engineers studies classified the 1987 event to be approximately a 100-year event in the Spicket watershed. The 1996 rainfall was more significant and occurred over a much shorter duration than the 1987 event, however, there was no additional runoff from snowmelt for this recent event. The August 1955 event was the most significant event to occur in the greater Boston area including the Neponset River. It was the result of about 13-16 inches of rainfall from 17-20 August for the Neponset area. Past Corps of Engineers studies classified the 1955 event to be about a 100-year event in the Neponset watershed. The January 1979 event was the result of about 7 inches of rainfall that fell on 21 and 24 to 25 January producing significant runoff in the Aberjona and Shawsheen watersheds. This rainfall is somewhat less than occurred in 1996, however, in addition to the rainfall, frozen grounds resulted in minimal infiltration losses and snowmelt also contributed to runoff amounts for the 1979 rainfall event.

Based on the total rainfall data, the October 1996 event was more significant than the 1955, 1987 and 1979 events. However, storm events can not be characterized by rainfall only, as other factors can effect flooding. Analysis of recorded flow data and water elevations were also performed and are presented below.

5. DISCHARGE FREQUENCIES

a. Purpose and Scope

This section describes the peak runoff of October 1996 and its effect on previously computed flood frequencies, along with comparing it to previous floods. Acknowledgement is made to the United States Geological Survey (USGS) for their cooperation in providing much of the preliminary flood discharge data for this analysis.

In addition to the rainfall data, peak discharge data were gathered for 18 gages in the area. The precipitation event of 20-21 October 1996 resulted in moderate to significant runoff peaks on many streams in northeastern Massachusetts and coastal New Hampshire. The peak discharge data were analyzed to determine the return interval of this runoff event.

b. October 1996 Peak Discharges

Flood discharges were obtained from the records of the USGS stream gaging stations which are located in the study area. The locations of these gaging stations in the region affected by the flood are shown on Plate 8 and are listed by gage number. A comparative summary of data collected by the USGS for the October 1996 flood and the maximum flood discharge previously known are shown on table 3.

Of the 18 gaging stations studied, only 3 resulted in discharges which exceeded the previous maximum of record, for this event. Peak discharges for this event exceeded previous peaks of record for the Parker River at Byfield and the Shawsheen River near Wilmington, Massachusetts, and the Oyster River near Durham, New Hampshire. Peak discharges for Parker and Shawsheen Rivers exceeded previous peak discharges by 10 percent whereas, Oyster River peak was only slightly higher than the previous recorded peak.

This event also produced the second largest peak flows of record at the Ipswich River near Ipswich, the Ipswich River at South Middleton, Aberjona River at Winchester, and Nashoba Brook near Acton, Massachusetts, along with the Lamprey River near Newmarket, New Hampshire. The peak discharges for this event were about 85-95 percent of the historic peak discharges recorded at these gages.

c. Effect of October 1996 Flood on Discharge Frequencies

Peak discharge frequencies were developed for rivers in the region by analysis of flow records at the USGS gaging stations. The gages have varying periods of record ranging from 10 to 66 years, with the majority recording for approximately 60 years. The Corps of Engineers HEC-FFA Flood Frequency Analysis computer program was used to analyze the systematic records of annual peak flows, including the October 1996 peak. The data were analyzed in log Pearson Type III distributions. Adopted skews were generally based on a weighted value of the

TABLE 3
DISCHARGE DATA FOR STREAMS STUDIED IN MASSACHUSETTS
AND NEW HAMPSHIRE OCTOBER 1996

USGS Gage Number	Stream and Location	Drain age area (Mi ²)	Period of record used for Recurrence interval	Maximum flood previously known		Maximum during Oct 1996 Flood			
				Date	Discharge (CFS)	Date	Discharge CFS	Cfs per Mi ²	Recurrence interval (yrs)
101000	Parker R. at Byfield	21.3	1946-1995, 1997	4-07-87	790	10-96	883	41	100
073500	Lamprey R. near Newmarket	183	1934-1997	4-07-87	7,570	10-96	7,200	39	75
073000	Oyster R. near Durham, NH	12.1	1935-1995, 1997	9-11-54	862	10-96	865	72	60
100600	Shawsheen R. near Wilmington	36.5	1963-1995, 1997	1-26-79	1,660	10-96	1,850	51	50
102500	Aberjona R. at Winchester	24.1	1939-1995, 1997	1-25-79	1,330	10-96	1,150	48	40
102000	Ipswich R. near Ipswich	125.0	1931-1995, 1997	4-08-87	3,550	10-96	3,030	24	35
101500	Ipswich R. at South Middleton, MA	44.5	1938-1995, 1997	4-07-87	1,010	10-96	896	20	25
097300	Nashoba B. near Acton, MA	12.8	1964-1995, 1997	1-26-79	679	10-96	599	47	25
104500	Charles R. at Waltham, Ma	251	1932-1995, 1997	2-03-76	4,150*	10-96	2,990	12	20

*Affected by upstream releases

TABLE 3 (CONT.)

USGS Gage Number	Stream and Location	Drainage area (Mi ²)	Period of record used for Recurrence interval	Maximum flood previously known		Maximum during Oct 1996 Flood			
				Date	Discharge (CFS)	Date	Discharge CFS	Cfs per Mi ²	Recurrence interval (yrs)
096000	Squannacook R. near West Groton, MA	65.9	1950-1995, 1997	4-06-87	4,220	10-96	3,330	50	15
105000	Neponset R. at Norwood	34.7	1939-1995, 1997	8-19-55	1,490	10-96	710	20	10
965852	Beaver B. at N. Pelham, MA	47.8	1987-1989, 1991-1997	4-06-87	1,850	10-96	1,550	32	8
105500	E.B. Neponset River at Canton, MA	27.2	1953-1995, 1997	'55 & '73	1,790	10-96	818	30	7
96500	Nashua R. at E. Pepperell, MA	435	1936-1995, 1997	3-20-36	20,900	10-96	5,910	14	6
99500	Concord R. at Lowell, MA	400	1938-1995, 1997	1-28-79	5,410	10-96	3,300	8	5
97000	Assabet River at Maynard, MA	116	1942-1995, 1997	8-20-55	4,250	10-96	1,550	15	4
103500	Charles R. at Dover, MA	183.0	1936, 1938-1995, 1997	8-23-55	3,220	10-96	1,370	8	3
98530	Sudbury River at Saxonville, MA	106	1980-1995, 1997	6-07-82	2,420	10-96	1,150	10	3

computed skew for the period of record and the generalized skew. Generalized skew coefficients were given more weight for gages with shorter record and computed skews were given more weight for gages with long periods of record. Generalized skew coefficients, as outlined in Bulletin 17B, ranged from 0.7 in the lower part of the study area to 0.5 for the Oyster River in New Hampshire. The magnitude of this event necessitated the updating of any existing frequency curves to include the additional years of recent record along with the October 1996 peak flow. The effect of this updating tended to make the occurrence of a flood of a given magnitude more frequent. For example, comparing the Parker River October 1996 peak flow of 883 cfs with an existing frequency curve with a period of record of 1946 -1987 indicated a 150-year event, however, after updating the systematic record of peak flow values to include 10 more years of data, along with October 1996 peak, the same flow of 883 cfs would have a 100-year return interval.

The adopted frequencies were developed by statistical analysis of recorded data. Presented as Appendix B are the adopted discharge frequency curves for 18 gages in the study area. The October 1996 peak flow along with other significant events are shown on each curve. Table 3 shows the estimated recurrence interval of the peak flows for the October 1996 event for all the gages. Generally the event produced peak discharges with return intervals of 20-year or greater for areas north of Boston and east of Route 495, along with coastal New Hampshire. Areas of the north-shore in Massachusetts and coastal New Hampshire resulted in peak discharges with a return interval of 50-years or greater, with the Parker River Basin approaching a 1 percent (100-year) chance event. Plate 9 shows the approximate limits of where peak discharges equal or exceed 20- and 50-year events for this storm.

For the rivers where the high water marks were taken, the return intervals of this event ranged from 10- to 100-year. Based on flows at the Neponset gage, this event was approximately a 10-year event, which is in agreement with other gages in the area. Flow at the Aberjona gage correlated to a 40-year event and at the Shawsheen gage a 50-year event. The recorded flows at the Oyster and Lamprey Rivers gages, compared to their adopted frequencies, resulted in return intervals of 60- and 75-years, respectively. The Parker River, located adjacent to the Spicket River, resulted in a 100-year event at its gage.

d. Comparisons With Other Floods

As stated earlier, only 3 of the 18 gages studied resulted in recorded discharges that exceeded previous historic peaks for this event. Table 4 presents a comparison of October 1996 peak flows to past peak flows, for the areas where highwater marks were taken. As can be seen, previous peak discharges were mostly attributable to three events. To the south of Boston the August 1955 generally produced the peaks of record. In the center of the study area (Aberjona and Shawsheen watersheds) the January 1979 event produced peaks and previous peaks of record. Generally, in areas of northern Massachusetts and coastal New Hampshire the March/April 1987 event produced previous peaks of record in this region. The 1996 event, based on peak flow data, was not the most severe event to occur in this area.

TABLE 4
Peak Discharges of Past Significant Events

USGS GAGE/ Watercourse	Comparison of Past Significant Peak Flows (cfs)					
	Oct 96	Mar/Apr 87	Jan 79	Mar 68	Aug 55	Mar 36
Parker River at Byfield	883	790	361	489	**	-
Shawsheen River at Wilmington	1,850	1,200	1,660	1,050	-	-
Spicket River * in Methuen	~2,000	~2,300	-	~1,440	-	-
Aberjona River at Winchester	1,150	877	1,330	649	686	-
Neponset River at Norwood	710	691	837	1,140	1,490	-
Lamprey River near New Market	7,200	7,570	**	3,220	**	5,490

* Flows estimated from highwater marks, not recorded at gage

** Not peak for water year

- Gage not installed yet

6. HIGH WATER MARK COMPARISONS

a. General

This section presents a summary of the locations and elevations of high water marks recorded after the October 1996 flood. Included is a comparison of the measured high water mark elevations to the existing Flood Insurance Study (FIS) elevations at each location. Also included are estimates of peak discharges at each location for this event, along with comparisons to FIS flows. High water elevations presented in this report are surveyed elevations of the estimated maximum river levels which occurred during the storm. High water elevations are of interest to FEMA mitigation employees and affected community officials for defining the impacts of flooding, and to locate potential development above flood levels.

b. High Water Data

On October 26 - November 6, 1996, NED mobilized two-person teams to mark and record locations of identifiable high waters. Where possible the high water marks were identified by debris lines that remained. At many sites, local residence and public officials were consulted for assistance in determining high water elevations. The teams (names listed below rivers) were sent out to the following rivers:

Shawsheen River (Lawrence, Andover, Tewksbury, Billerica, and Bedford, MA)

Team: Scott Accone and Bob Russo

Spicket River (Lawrence and Methuen, MA and Salem, NH)

Team: Heather Sullivan, Carmen Suarez, and Brian Waz

Aberjona River (Winchester and Woburn, MA)

Team: Dave Larson and Townsend Barker

Alewife Brook (Arlington and Cambridge, MA)

Team: John Kedzierski and Wendal Mah

Neponset River (Milton, Canton, and Norwood, MA)

Team: Ulrika Volz and Chris Hatfield

Lamprey River (Epping, NH)

Team: John Kedzierski and Chris Hatfield

Little River (North Hampton, NH)

Team: John Kedzierski and Chris Hatfield

Plate 1 shows the locations of these rivers. The teams were instructed to locate and flag sufficient high water marks along these rivers to adequately document the storm. Locations were marked with paint, stakes, engineer tape, and nails. Site description and other pertinent information were recorded on NED standard forms for high water mark data collection. This information is included under separate cover titled "High Water Marks Report For Storm Event of October 20-21, 1996" dated April 1997. Photographs and sketches of the site were also used to aid survey personnel in recovering the marks to determine the elevations. In February and March 1997, survey crews from NED obtained the elevations of high water marks.

High water marks and the corresponding elevations, referenced to the National Geodetic Vertical Datum (NGVD), are listed in table 5. The high water marks are listed from downstream to upstream for each of the rivers, therefore, not necessarily in the assigned high water number order. Also included in table 5 are the corresponding FIS 10-, 50-, 100-, and 500-year elevations at each location. Each of the high water marks were also plotted on existing FIS profile sheets

TABLE 5
COMPARISON OF HIGH WATER MARKS TO
EXISTING FLOOD INSURANCE STUDY ELEVATIONS

SPICKET RIVER						
HWM NO.	CITY/ TOWN	ELEVATIONS (IN FEET NGVD)				
		Oct 1996 HWM	FIS 10-YEAR	FIS 50-YEAR	FIS 100-YEAR	FIS 500-YEAR
SP-1	Lawrence	51.92	44.9	47.5	49.0	52.1
SP-2	"	47.93	45.5	48.7	50.8	53.5
SP-3	"	49.05	45.5	48.7	50.8	53.5
SP-4	"	49.53	45.8	49.0	51.1	53.8
SP-5	"	49.79	45.9	49.2	51.3	53.9
SP-6	"	51.32	45.9	49.2	51.3	53.9
SP-7	"	49.84	46.9	49.8	51.5	54.0
SP-8	"	49.71	46.9	49.8	51.5	54.0
SP-9	"	51.74	47.0	50.3	52.2	55.2
SP-10	Methuen	59.66	57.4	59.0	60.0	63.0
SP-11	"	63.78	59.0	60.7	61.9	64.7
SP-12	"	75.12	69.5	71.0	72.0	73.6
SP-13	"	112.11	104.7	107.5	107.9	111.0
SP-14	Salem, NH	111.65	109.5	112.0	112.5	114.3
SP-15	"	111.85	110.0	112.0	112.7	114.4
SP-16	"	112.59	110.3	112.0	112.7	114.4
SP-17	"	115.29	111.0	112.0	113.1	114.8
SP-18	"	118.00	112.5	114.5	115.7	118.6
SP-19	"	117.47	117.5	119.2	120.0	121.8
SP-20	"	122.22	119.0	120.8	122.3	125.0

TABLE 5 (CONT.)

ABERJONA RIVER						
HWM NO.	CITY/TOWN	ELEVATION (IN FEET NGVD)				
		Oct 1996 HWM	FIS 10-YEAR	FIS 50-YEAR	FIS 100-YEAR	FIS 500-YEAR
AB-11	Winchester	15.98	13.1	15.0	15.8	18.0
AB-19	"	19.98	15.6	17.3	18.2	20.1
AB-10	"	20.85	17.3	18.2	19.0	20.9
AB-8	"	22.34	18.2	19.5	20.5	23.8
AB-7	"	28.67	20.3	22.4	23.5	25.7
AB-6	"	27.28	21.1	23.0	23.7	25.9
AB-18	"	27.16	21.9	24.1	25.3	29.1
AB-5	"	26.97	22.5	24.4	25.5	29.2
AB-4	"	27.23	22.8	24.8	25.9	29.4
AB-3	"	27.21	25.5	26.8	27.4	29.5
AB-2	"	31.52	27.5	30.5	30.9	31.5
AB-12	Woburn	39.94	37.5	38.3	38.6	39.3
AB-17	"	49.58	45.5	46.0	46.3	46.8
AB-15	"	52.97	Mark effected by Split Brook flooding			
AB-14	"	53.11	"			
AB-13	"	51.81	49.0	50.0	50.5	51.1
AB-16	"	52.85	49.6	50.6	51.0	51.5
HORN POND BROOK (Tributary to Aberjona River)						
HWM NO.	CITY/TOWN	ELEVATION (IN FEET NGVD)				
		Oct 1996 HWM	FIS 10-YEAR	FIS 50-YEAR	FIS 100-YEAR	FIS 500-YEAR
AB-9	Winchester	27.05	18.3	19.7	20.8	23.8
AB-1	Winchester	24.60	20.6	22.4	23.3	24.6

TABLE 5 (CONT.)

SHAWSHEEN RIVER						
HWM NO.	CITY/TOWN	ELEVATION (IN FEET NGVD)				
		Oct 1996 HWM	FIS 10-YEAR	FIS 50-YEAR	FIS 100-YEAR	FIS 500-YEAR
SH-13	Lawrence	29.28	25.9	31.0	34.3	41.0
SH-12	Andover	34.30	32.0	35.0	36.3	44.0
SH-11	"	36.90	34.4	37.0	37.9	44.5
SH-10	"	69.69	69.4	70.3	70.7	71.6
SH-9	Tewksbury	83.70	83.4	84.9	85.5	86.8
SH-8	"	86.28	84.5	86.0	86.8	88.0
SH-7	"	87.51	86.5	87.8	88.3	89.5
SH-6	Billerica	98.96	95.0	98.5	99.0	100.4
SH-5	Bedford	100.80	96.3	99.0	100.0	101.5
SH-4	"	105.76	FIS elevations could be high due to larger bridge opening			
SH-3	"	110.21	108.0	109.5	110.5	112.5
SH-2	"	112.44	110.0	111.5	112.5	115.0
SH-1	"	115.80	114.3	115.3	116.0	118.0

ALEWIFE BROOK

HWM NO.	CITY/TOWN	ELEVATIONS (IN FEET NGVD)				
		Oct 1996 HWM	FIS 10-YEAR	FIS 50-YEAR	FIS 100-YEAR	FIS 500-YEAR
A-1	Arlington/Cambridge	5.65	5.4	7.0	8.9	10.2
C-1	Cambridge	8.86	5.5	7.3	8.2	10.5
C-2	Cambridge	8.97	5.5	7.4	8.2	10.5

TABLE 5 (CONT.)

LAMPREY RIVER

HWM NO.	CITY/ TOWN	ELEVATION (IN FEET NGVD)				
		Oct 1996 HWM	FIS 10-YEAR	FIS 50-YEAR	FIS 100-YEAR	FIS 500-YEAR
E-1	Epping, NH	112.03	108.0	109.8	110.5	112.0
E-2	Epping, NH	139.36	135.2	137.8	138.8	141.0

LITTLE RIVER

HWM NO.	CITY/ TOWN	ELEVATION (IN FEET NGVD)				
		Oct 1996 HWM	FIS 10-YEAR	FIS 50-YEAR	FIS 100-YEAR	FIS 500-YEAR
NH-1	N. Hampton, NH	10.98	high water mark is downstream of profile limits			
NH-2	N. Hampton, NH	10.85	"			

NEPONSET RIVER

HWM NO.	CITY/ TOWN	ELEVATION (IN FEET NGVD)				
		Oct 1996 HWM	FIS 10-YEAR	FIS 50-YEAR	FIS 100-YEAR	FIS 500-YEAR
M-1	Milton	17.73	15.9	16.8	17.3	18.0
C-1	Concord	45.36	45.7	47.3	48.1	51.8
N-1	Norwood	58.30	57.5	60.3	60.8	62.3

HAWES BROOK (Tributary to Neponset River)

HWM NO.	CITY/ TOWN	ELEVATION (IN FEET NGVD)				
		Oct 1996 HWM	FIS 10-YEAR	FIS 50-YEAR	FIS 100-YEAR	FIS 500-YEAR
N-3	Norwood	76.00	77.8	79.2	81.5	88.2
N-2	Norwood	79.99	80.8	81.7	82.6	89.0

and are presented in Appendix C. When available, high water elevations for previous floods were also plotted. In addition to the seven rivers listed above, high water marks were located on two tributaries, which are also included in table 5. Two marks were located on Horn Pond Brook near its confluence with the Aberjona River in Winchester and two marks were located on Hawes Brook near its confluence with the Neponset River in Norwood. Each of the high water marks were also plotted on existing profiles sheets from the FIS.

Some inconsistencies may possibly be due to misinterpretations of high water marks, or surveying errors. Debris lines are not always reliable as they may reflect wave action on one bank of a river but not on the opposite side, there may be ride-up on the outside of sharp bends or backwater conditions from local tributary flow. As it is difficult at times to comprehend the vagaries of flood profiles, one should be cautioned in their interpretation.

c. Estimated October 1996 Peak Discharges at Ungaged Areas

Peak flows of the event were estimated at each high water mark location. Peak flow estimates were made by comparing the high water marks with the existing Flood Insurance Study elevations. Stage discharge rating curves were developed for each location using the reported FIS 10-, 50-, 100-, and 500-year flow and corresponding elevation shown on the profiles. From this rating curve and the October 1996 high water mark, the peak flow could be estimated.

Table 6 presents the estimated peak flow at each high water location for this event. Also included in the table are actual flow values recorded at USGS gages, where applicable. The estimated return interval (which is solely based on where the high water mark falls on the FIS profiles) is also presented for each. High water marks that were found to be unreliable or potentially erroneous (based on FIS data) have notations in the remarks column of the table. The approximate drainage areas that are listed in table 6 are as reported in the FIS's "table 1 - Summary of Discharges", for each location.

d. Comparison of Flows to Existing FIS Flows

As can be seen in table 6, the estimated peak flow on the ungaged Spicket River was generally about 2,000 cfs. This is comparable to the FIS 100-year peak flows for these areas. A previous Corps of Engineers study presented estimates of peak flows for the March/April 1987 of 2,000-2,400 cfs for this same area and adopted this as the 100-year flow. It should be noted that there is a slight discrepancy in the drainage area at the Methuen-Lawrence Corporate limits between the Methuen and Lawrence FIS's.

Flows on the Shawsheen River ranged from 2,000 cfs in Lawrence to 1,200 cfs in Bedford. As can be seen there is only a small reduction in flow compared to the large reduction in drainage areas from Lawrence to Bedford. At the downstream end, flows were less than the FIS 100-year flows, and flows at the USGS gage in Wilmington matched the FIS 500-year flow. Flows at the upstream end tended to match the FIS 100-year flow.

TABLE 6
ESTIMATES OF PEAK FLOWS FOR THE OCTOBER 1996 EVENT

SPICKET RIVER HIGH WATER MARKS						
HWM NO.	TOWN/CITY	ELEV FT. NGVD	APPROX. DA (MI ²)*	ESTIMATED FLOW (CFS)**	ESTIMATED FREQ **	REMARKS
SP-1	Lawrence	51.92	74.5	3,500	500-yr	? - higher than u/s marks
SP-2	"	47.93	74.5	1,900	<50-yr	
SP-3	"	49.05	74.5	2,000	50	
SP-4	"	49.53	74.5	2,100	50	
SP-5	"	49.79	74.5	2,100	50	
SP-6	"	51.32	74.5	2,400	100	? - same location as SP-5, higher than upstream marks
SP-7	"	49.84	72.0	1,800	50	
SP-8	"	49.71	72.0	1,800	50	
SP-9	"	51.74	72.0	2,050	100	
SP-10	Methuen	59.66	73.8	2,000	50-100	
SP-11	"	63.78	73.8	3,000	100-500	apears high
SP-12	"	75.12	73.8	4,000+	500+	apears high
SP-13	"	112.11	73.8	~3,800	500+	? - higher than u/s marks
SP-14	Salem, NH	111.65	61.6	1,450	50	
SP-15	"	111.85	61.6	1,500	50	
SP-16	"	112.59	61.6	1,800	100	
SP-17	"	115.29	61.6	3,000	500	apears high
SP-18	"	118.00	61.6	2,700	<500	higher than u/s mark
SP-19	"	117.47	61.6	900	10	
SP-20	"	122.22	47.9	1,600	100	

* As listed in the existing FIS (Summary of Discharges)

** Based on high water marks and rating curves developed from existing FIS

TABLE 6 (CONT.)

ABERJONA RIVER HIGH WATER MARKS						
HWM NO	TOWN/CITY	ELEV. FT NGVD	APPROX DA (MI ²)*	ESTIMATED FLOW (CFS)**	ESTIMATED FREQ **	REMARKS
AB-11	Winchester	15.98	26.6	1,350	100-yr	
USGS	"	-	24.7	1,150	100-yr	Actual flow recorded at Winchester gage
AB-19	"	19.98	24.7	1,825	500	higher than gage flow
AB-10	"	20.85	24.7	1,825	500	higher than gage flow
AB-8	"	22.34	24.7	1,600	100-500	higher than gage flow
AB-7	"	28.67	12.4	1,450	500+	higher than u/s marks
AB-6	"	27.28	12.4	1,250	500+	higher than gage flow
AB-18	"	27.16	12.4	850	100-500	
AB-5	"	26.97	12.4	850	100-500	
AB-4	"	27.23	12.4	850	100-500	
AB-3	"	27.21	11.6	650	100	
AB-2	"	31.52	11.6	950	500	
AB-12	Woburn	39.94	10.4	~1,100	500+	
AB-17	"	49.58	6.6	-	500++	mark exceeded rating
AB-15	"	52.97	5.5	-	500+	mark effected by Split Brook flooding?
AB-14	"	53.11	5.5	-	500+	mark effected by Split Brook flooding?
AB-13	"	51.81	5.5	~550	500+	
AB-16	"	52.85	5.5	~650	500+	

* As listed in the existing FIS (Summary of Discharges)

** Based on high water marks and rating curves developed from existing FIS

TABLE 6 (CONT.)

HORN POND BROOK HIGH WATER MARKS						
HWM NO.	TOWN/CITY	ELEV FT. NGVD	APPROX DA (MI ²)*	ESTIMATED FLOW (CFS)**	ESTIMATED FREQ.**	REMARKS
AB-9	Winchester	27.05	10.9	mark exceeded rating	500-yr++	much higer than u/s mark
AB-1	Winchester	24.60	10.9	1,090	500-yr	

SHAWSHEEN RIVER HIGH WATER MARKS						
HWM NO.	TOWN/CITY	ELEV FT. NGVD	APPROX DA (MI ²)*	ESTIMATED FLOW (CFS)**	ESTIMATED FREQ.**	REMARKS
SH-13	Lawrence	29.28	71.0	2,000	<50 -yr	FIS Profile shows Merrimack Backwater
SH-12	Andover	34.30	70.5	2,000	50-yr	
SH-11	"	36.90	70.5	2,100	50	
SH-10	"	69.69	70.5	1,700	10-50	
SH-9	Tewksbury	83.70	43.9	1,250	10-50	
SH-8	"	86.28	43.9	1,650	50	
SH-7	"	87.51	37.0	1,300	50	
USGS	Wilmington	-	36.5	1,850	500	Actual flow recorded at Wilmington gage
SH-6	Billerica	98.96	31.2	1,985	100	
SH-5	Bedford	100.80	27.2	2,200	<500	?
SH-4	"	105.76	16.5	not computed		Bridge opening bigger ?
SH-3	"	110.21	13.4	1,450	50-100	
SH-2	"	112.44	8.1	1,275	100	
SH-1	"	115.80	8.1	1,200	100	

* As listed in the existing FIS (Summary of Discharges)

** Based on high water marks and rating curves developed from existing FIS

TABLE 6 (CONT.)

ALEWIFE BROOK HIGH WATER MARKS						
HWM NO.	TOWN/CITY	ELEV. FT. NGVD	APPROX DA (MI ²)*	ESTIMATED FLOW (CFS)**	ESTIMATED FREQ. **	REMARKS
A-1	Arlington/Cambridge	5.65	6.53	300	10 -yr	Low HWM ?
C-1	Cambridge	8.86	6.53	575	100-500 -yr	
C-2	Cambridge	8.97	6.53	575	100-500 -yr	

LAMPREY RIVER HIGH WATER MARKS						
HWM NO.	TOWN/CITY	ELEV. FT. NGVD	APPROX DA (MI ²)*	ESTIMATED FLOW (CFS)**	ESTIMATED FREQ. **	REMARKS
USGS gage	New Market, NH	-	183	7,200	100-yr	Actual flow recorded at New Market gage
E-1	Epping, NH	112.03	112	6,300	500-yr	
E-2	Epping, NH	139.36	102	5,100	100-yr	

NEPONSET RIVER HIGH WATER MARKS						
HWM NO.	TOWN/CITY	ELEV. FT. NGVD	APPROX DA (MI ²)*	ESTIMATED FLOW (CFS)**	ESTIMATED FREQ. **	REMARKS
M-1	Milton	17.73	~95	4,200	100-500-yr	Uncertainty in mark
C-1	Canton	45.36	76.5	1,050	<10-yr	
USGS	Norwood	-	34.7	710	>10-yr	Actual flow recorded at Norwood gage
N-1	Norwood	58.30	26.2	550	>10-yr	

Hawes Brook - Both marks were below the 10-year profile, therefore, no flows were estimated.

* As listed in the existing FIS (Summary of Discharges)

** Based on high water marks and rating curves developed from existing FIS

Flows on the Aberjona were estimated to range from approximately 1,800 cfs in the downstream portion to about 500 cfs at the upstream limits of the high water marks. The FIS 100-year flows ranged from 1,310 cfs to 360 cfs for this same area. High water marks as compared to the existing FIS were in the 100- to 500-year range. The recorded flow at the USGS gage in Winchester was 1,150 cfs. The gage is located at the downstream end and is approximately the same as the FIS 100-year flow at that location.

Only three high water marks were obtained on Alewife Brook. One mark was obtained about 2,000 feet downstream of Route 2 and resulted in an estimated flow of about 300 cfs. Two marks were obtained about 1,000 feet upstream of Route 2, resulting in estimated flow of 575 cfs, for each. The FIS 100-year flow is the same for all three areas and is 500 cfs. There is a discrepancy between the downstream mark (10-year) and the two upstream marks (100- to 500-year).

Only two marks were obtained on Lamprey River. One matching the FIS 100-year flow and the other matching the 500-year flow. Further downstream the recorded flow at the USGS gage near New Market, NH was 7,200 cfs, which is in agreement with the FIS 100-year flow of 7,300 cfs at the same location.

Two of the three high water marks on the Neponset River are in agreement with the flow recorded at the USGS gage when compared by ratio of drainage areas. Estimates of peak flows for these two marks and the flow recorded at the gage were approximately the same as the FIS 10-year flow at each location. The one high water mark that is not in agreement and may be erroneous is the furthest downstream mark, which its estimated flow is in between the 100- and 500-year FIS flows at its location.

On the Little River, no flows were estimated because of the two high water marks, one appears to be on the ocean side of Ocean Boulevard and may have been affected by waves, and the other is located in a large storage (wetland) area at the mouth of the Little River. These marks were not located on FIS profiles sheets because they are downstream of the first profile sheet. The Little River profile starts about 2,500 feet downstream of Atlantic Avenue and the high water marks are located approximately 5,500 feet downstream of Atlantic Avenue.

e. Discussion.

High water mark elevations determined as a result of these surveys are meant only as a guide to assess the severity of flooding in an area. These high water marks are more appropriately used for estimating high water elevations for a region rather than for a specific site. Individual marks may not accurately represent the water elevation experienced at a particular site. Moreover, trends in water levels occurring in a particular region may be determined when these marks are evaluated as a group rather than individually. The major source of error in this data is due to the inherent subjectiveness of estimating high water levels from residual debris after a storm has passed.

7. SUMMARY

Heavy rainfall from October 20-21, 1996 caused high river stages and extensive flooding throughout eastern Massachusetts, southern New Hampshire, and Maine. In an effort to characterize this event in terms of return frequency, recorded rainfall and discharge data and high water mark data were obtained and evaluated. This information, along with past flood event data, provides an indication of the severity of this event in relation to other historic floods.

Rainfall totals ranged from 6 to 13 inches for northeast Massachusetts, coastal New Hampshire and southeastern Maine, and when compared with National Weather Service published rainfall frequency data, were generally in excess of a 100-year (1 percent chance) event. However, it should be noted that the published TP-40 and TP-49 rainfall frequency data were developed from rainfall records only through 1961. There are ongoing discussions in the Weather Service on the need for updating this data to include the additional 36 years of rainfall data for this area. In addition, characterizing a storm is not only a function of rainfall frequency but also a function of runoff frequency.

This rainfall caused significant rise in all rivers within this region. However, peak discharges in many cases were lower than might be expected, pointing out the important distinction between rainfall frequency and runoff frequency. Flood discharges of the event were obtained from records of the U.S.G.S. stream gaging stations in the study area. Of the 18 gaging stations studied, only 3 resulted in discharges which exceeded the previous maxima of record, and five which resulted in the second highest recorded peaks. Generally the event produced peak discharges with return intervals of 20-year or greater for areas north of Boston and east of Route 495, along with coastal New Hampshire. Areas of the north-shore in Massachusetts and coastal New Hampshire resulted in peak discharges with a return interval of 50-years or greater. The most notable peak discharge during the two day period occurred on the Parker River at Byfield gage. The recorded peak flow exceeded the previous peak by 10 percent and resulted in a 100-year discharge.

Surveyed high water mark data were obtained for selected rivers, where there was known flooding or current Corps of Engineers studies. This data was analyzed and compared with existing Flood Insurance Profiles to estimate peak discharges at areas with no recording gages. When compared to the FIS profile data, the high water marks ranged in return frequencies. The majority of the high water marks plotted were above the 50-year profiles and below the 500-year profiles. However, some of the marks plotted were well above the 500-year profile and some were as low as the 10-year profile. Table 7 is a comparison of the estimated return intervals of all the data analyzed for the selected rivers where high water data were obtained.

TABLE 7
Summary of October 1996 Storm Event Data

Watercourse	Comparison of Return Intervals (in years)			
	Estimated Rainfall Frequency	Estimated Discharge Frequency	Estimated Stage Frequency from HWM and FIS Profiles	Adopted Frequency of Runoff Event
Shawsheen River	100+	50	50-100	50-100
Spicket River	100+	-	50-100	<100
Parker River	100+	100	500	100
Aberjona River	100+	40	100-500	40-100
Alewife Brook	100+	-	10-500	<100
Lamprey River	100+	75	100	75-100
Little River	100+	-	500+	-
Neponset River	lower 50-100 upper 20-50	10	10-100	10

Of the 17 Flood Insurance Studies covering the area where high water marks were obtained, only 3 were completed after April 1987, and 2 were revised after 1987. Therefore, they do not include flow data for two of the more significant runoff events on record. For example the Parker River FIS was done in 1986, since its completion the two largest flood events ever recorded at the Parker River at Byfield gage have occurred in April 1987 and October 1996. This is also true for communities on the Shawsheen and Ipswich Rivers, however, some of the FIS's have been revised after 1987. Updating the discharge frequency data to include the recent high flow events would tend to result in larger 1 percent chance flows at those gages.

8. REFERENCES

- a. U.S. Interagency Advisory Committee on Water Data, Bulletin 17B, "Guidelines for Determining Flood Flow Frequency", March 1982.
- b. Federal Emergency Management Agency, Flood Insurance Studies
 - 1. City of Lawrence, MA, dated February 2, 1982
 - 2. City of Methuen, MA, dated June 18, 1987
 - 3. Town of Salem, NH, dated December 1978
 - 4. Town of Andover, MA, Revised June 5, 1989
 - 5. Town of Tewksbury, MA, dated January 2, 1981
 - 6. Town of Wilmington, MA, Revised January 18, 1989
 - 7. Town of Billerica, MA, dated February 1985
 - 8. Town of Bedford, MA, dated July 4, 1988
 - 9. Town of Newbury, MA, dated July 17, 1986
 - 10. Town of Winchester, MA, dated December 1979
 - 11. Town of Woburn, MA, dated January 1980
 - 12. City of Cambridge, MA, dated January 5, 1982
 - 13. Town of Milton, MA, dated March 1977
 - 14. Town of Canton, MA, dated June 4, 1987
 - 15. Town of Norwood, MA, dated June 1979
 - 16. Town of Epping, NH, dated October 15, 1981
 - 17. Town of North Hampton, NH, dated June 3, 1986
- c. U.S. Weather Bureau, Technical Paper No. 40, dated May 1961
- d. U.S. Weather Bureau, Technical Paper No. 49, dated 1964

CANADA

N.Y.



VT.
MONTPELIER

N.H.

MAINE

O AUGUSTA

ATLANTIC

OCEAN

N.Y.

LAMPREY RIVER WATERSHED

SPICKET RIVER WATERSHED

SHAWSHEEN RIVER WATERSHED

NEPONSET RIVER WATERSHED

LITTLE RIVER WATERSHED

ABERJONA RIVER WATERSHED

ALEWIFE BROOK WATERSHED

MASS.

SCALE IN MILES



US Army Corps of Engineers
New England District
Waltham, Massachusetts

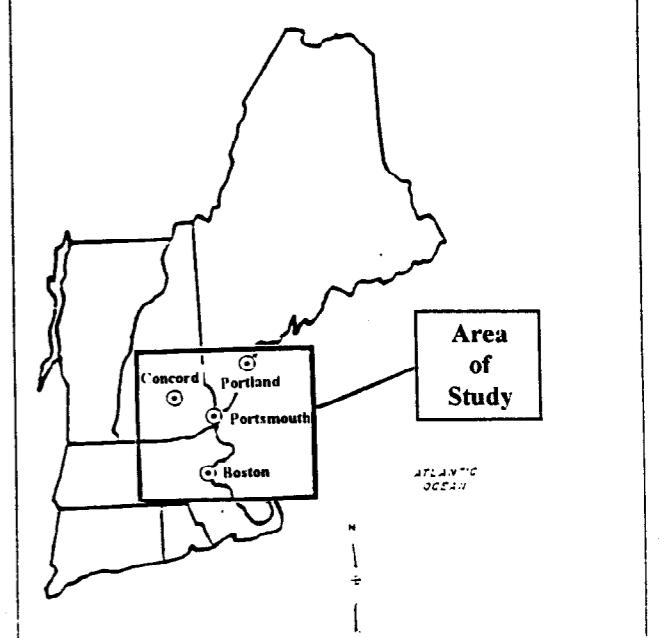
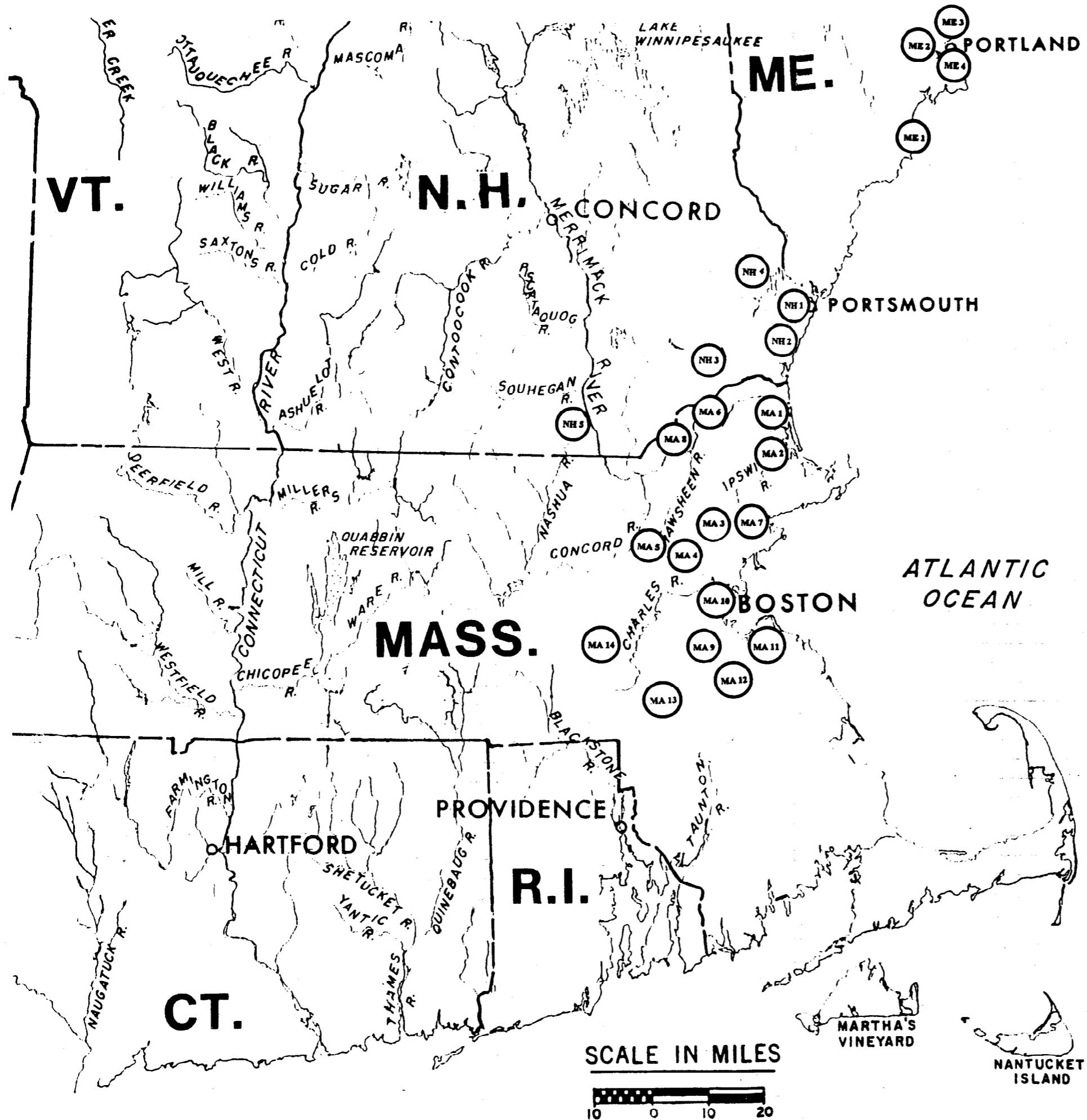
OCTOBER 1996 FLOOD
REGIONAL ANALYSIS

STUDY AREA WATERSHEDS

WMS

MAY 1997

PLATE 1



Detail Map

Index to Rainfall Gaging Stations October 20-21, 1996		
Station	Location	Total Rainfall (Inches)
MA 1	Newburyport	13.0
MA 2	Ipswich	11.2
MA 3	Wakefield	10.6
MA 4	Woburn	10.5
MA 5	Bedford	10.0
MA 6	Haverhill	10.0
MA 7	Peabody	9.5
MA 8	Lawrence	8.8
MA 9	Blue Hill	8.5
MA 10	Boston	7.9
MA 11	Hingham	7.9
MA 12	Randolph	7.6
MA 13	Walpole	6.8
MA 14	Natick	6.8
ME 1	Camp Ellis	19.2
ME 2	Gorham	19.0
ME 3	Westbrook	17.6
ME 4	Portland	12.6
NH 1	Portsmouth	12.2
NH 2	Greenland	12.9
NH 3	Epping	9.8
NH 4	Durham	9.6
NH 5	Nashua	6.8

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New England District
Waltham, Massachusetts

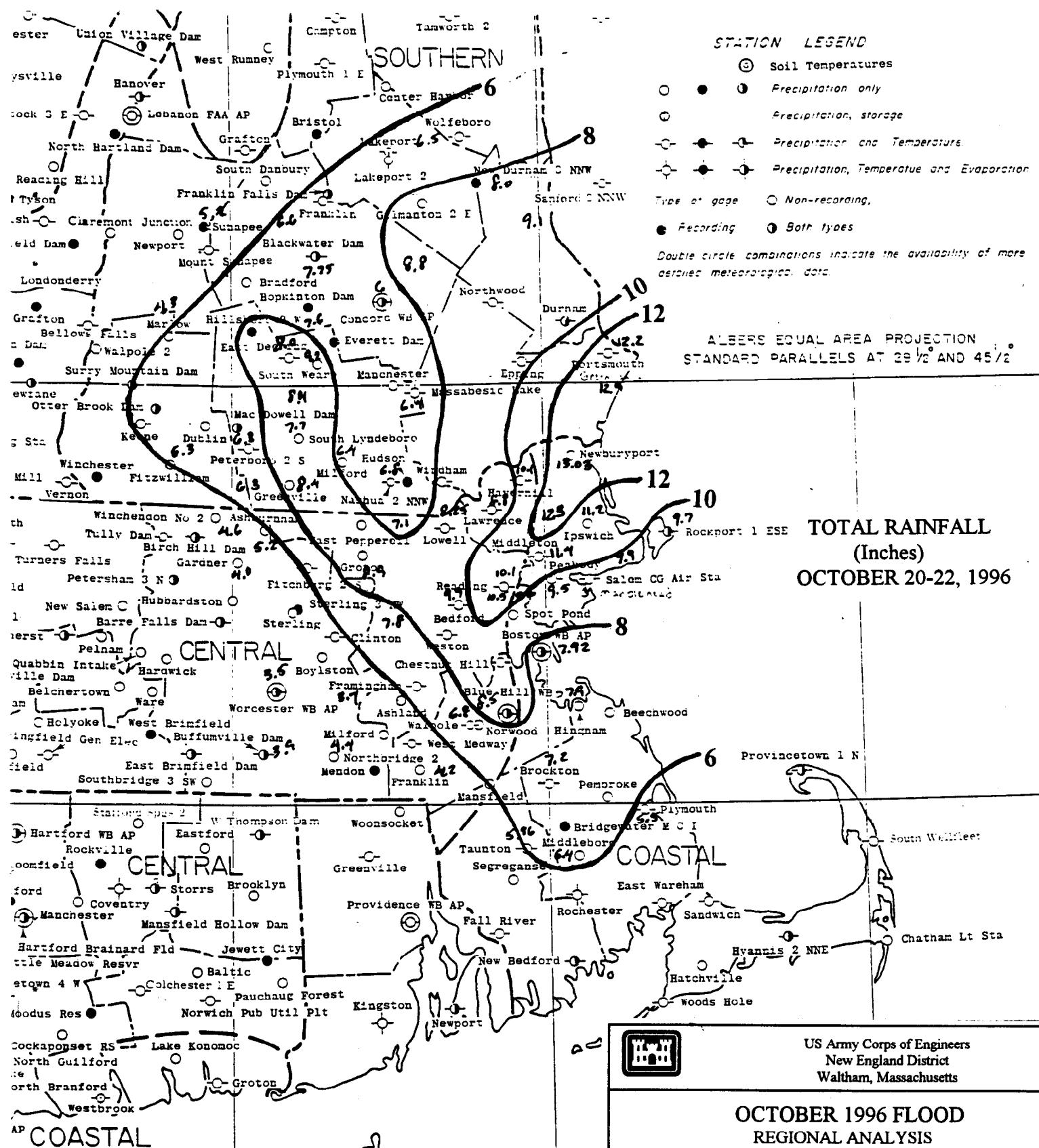
OCTOBER 1996 FLOOD
REGIONAL ANALYSIS

RAINFALL INDEX MAP

WMS

MAY 1997

PLATE 1



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Waltham, Massachusetts

OCTOBER 1996 FLOOD
REGIONAL ANALYSIS

ISOHYETAL MAP

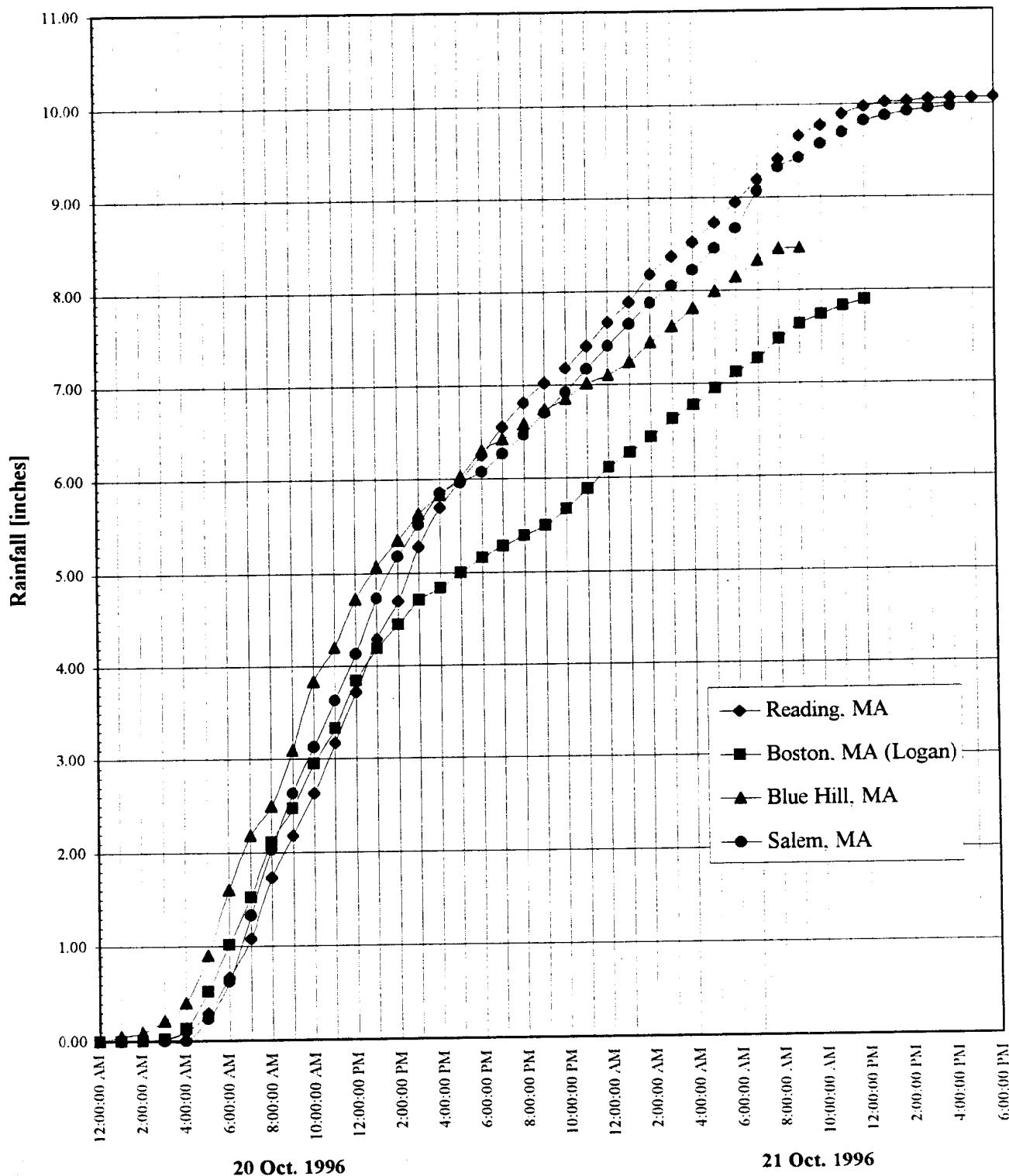
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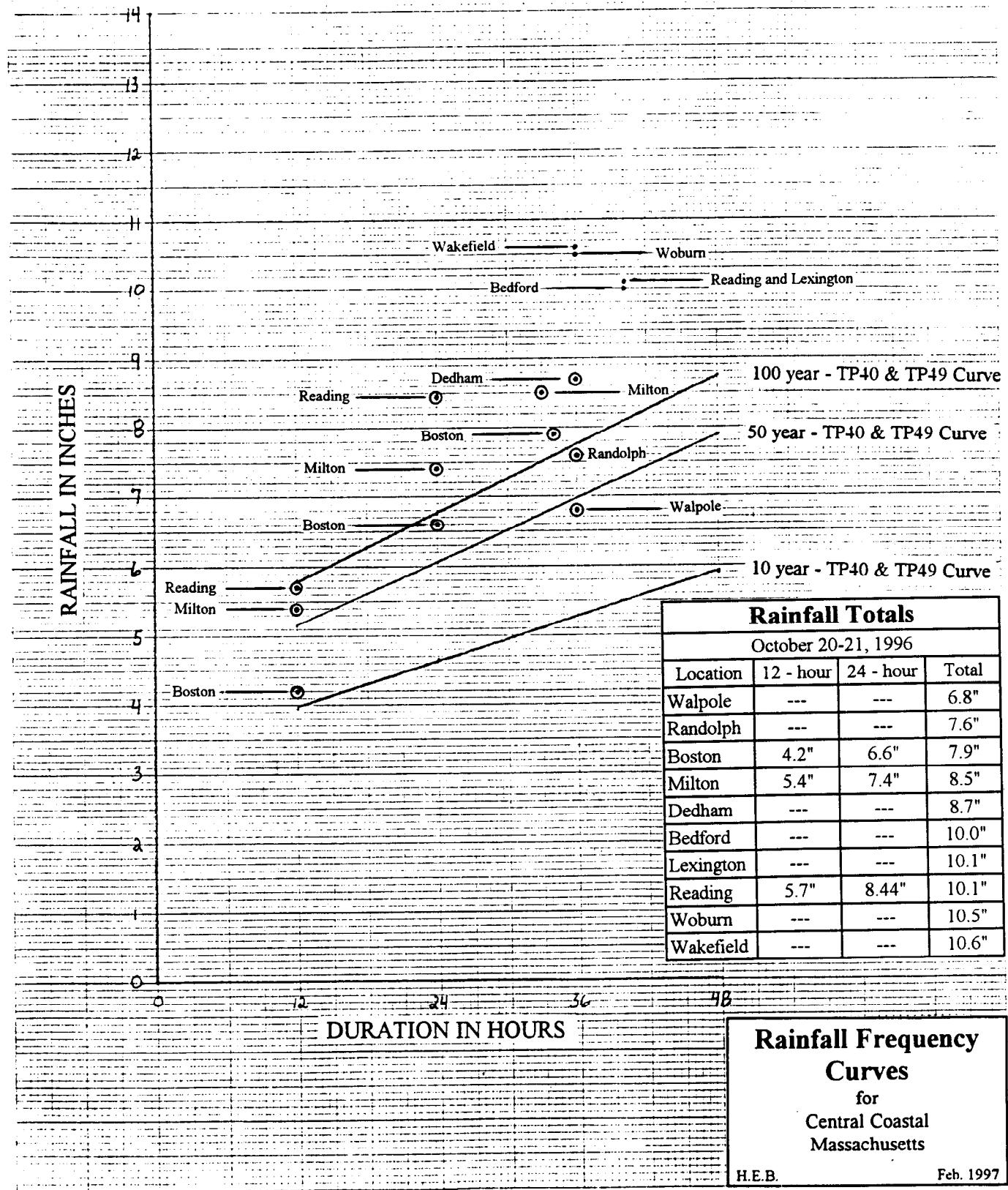
MAY 1997

PLATE 3

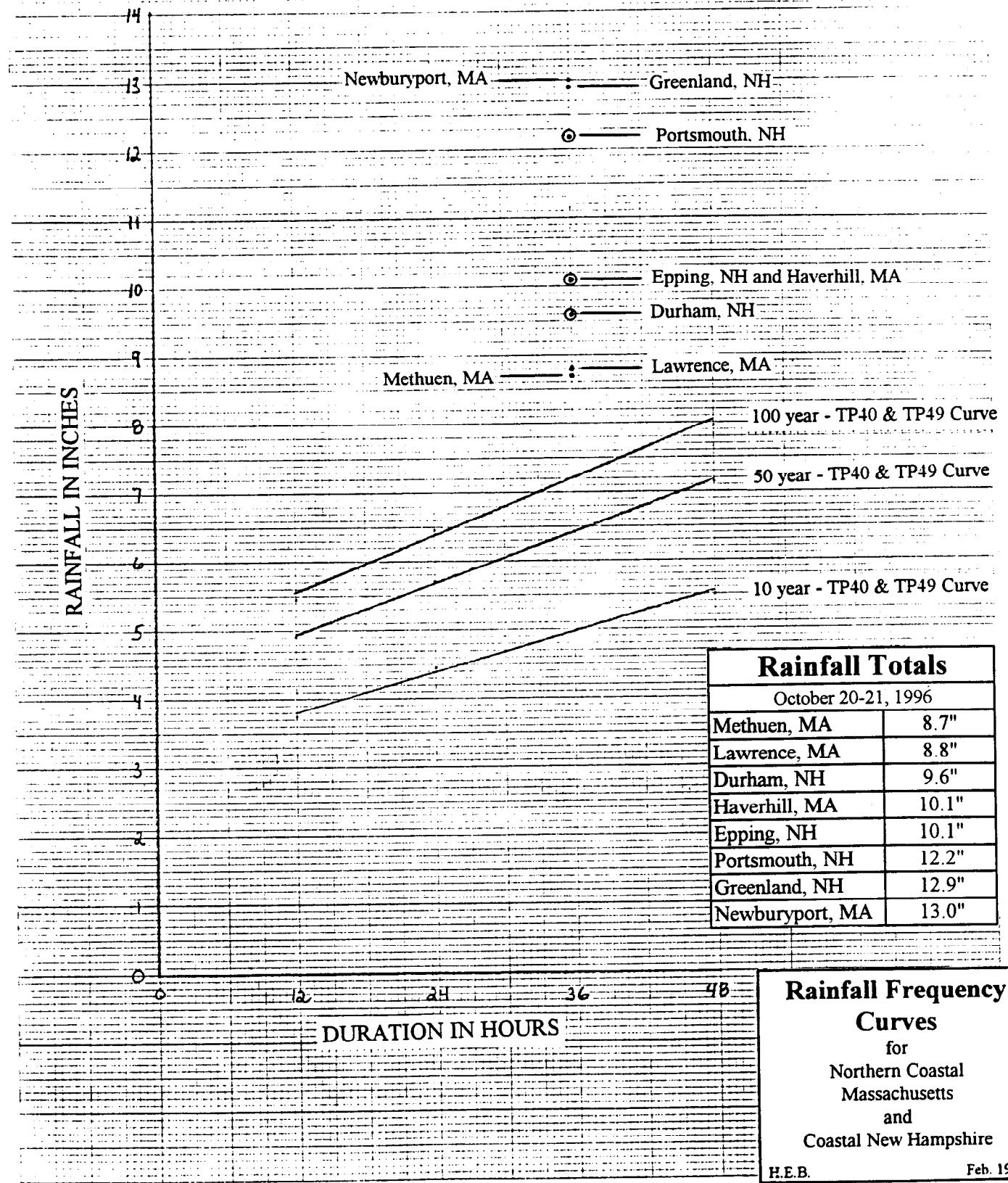
Mass Rainfall Curves

October 20-21, 1996 Event





6 1373



NEW HAMPSHIRE



20-YEAR 50-YEAR
100-YEAR

APPROXIMATE LIMITS
OF RETURN INTERVALS
OF RAINFALL
(years)

100-YEAR
50-YEAR
20-YEAR

ATLANTIC
OCEAN

MASSACHUSETTS



US Army Corps of Engineers
New England District
Waltham, Massachusetts

OCTOBER 1996 FLOOD REGIONAL ANALYSIS

APPROXIMATE RETURN INTERVAL
LIMITS OF OCTOBER 1996
RAINFALL

WMS

MAY 1997

DATE

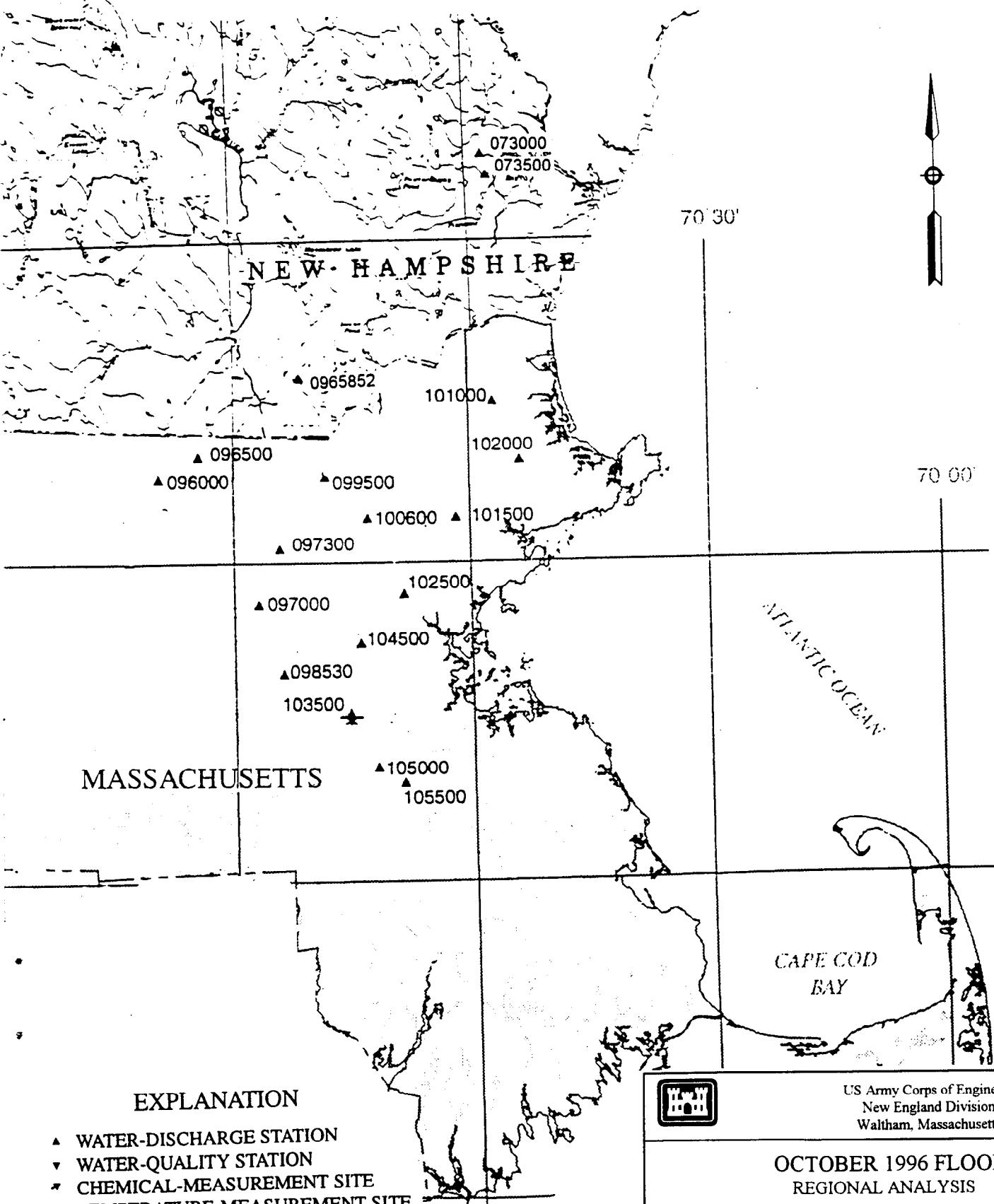
STATION LEGEND

DATA PUBLISHED IN

- CLIMATOLOGICAL DATA
- HOURLY PRECIPITATION DATA
- △ CLIMATOLOGICAL DATA AND
HOURLY PRECIPITATION DATA

For further information, refer to the
station index and references notes.

0 10 20 30 40 50 60 70
0 10 20 30 40 50 60 70
80 MILES
80 KILOMETERS



STATION NUMBERS ARE IN ABBREVIATED FORM:
THE FIRST TWO DIGITS ARE OMITTED, FOR EXAMPLE
STATION NUMBER 01176000 IS SHOWN ABOVE AS 176000

US Army Corps of Engineers
New England Division
Waltham, Massachusetts

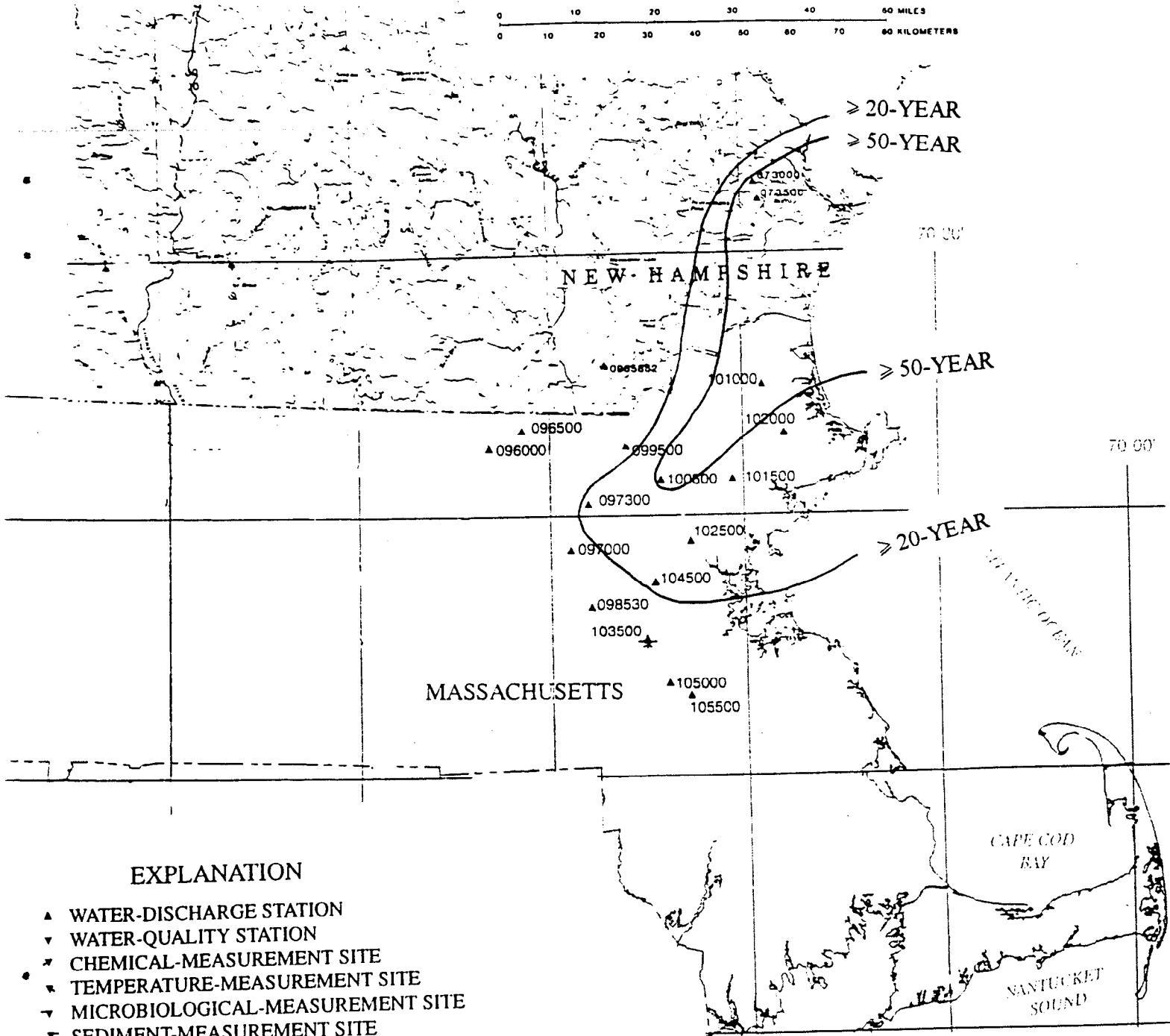
OCTOBER 1996 FLOOD
REGIONAL ANALYSIS

LOCATIONS OF U.S.G.S GAGING
STATIONS USED IN THE ANALYSIS

WMS

MAY 1997

PLATE 8



EXPLANATION

- ▲ WATER-DISCHARGE STATION
- ▼ WATER-QUALITY STATION
- ↗ CHEMICAL-MEASUREMENT SITE
- ↘ TEMPERATURE-MEASUREMENT SITE
- ▼ MICROBIOLOGICAL-MEASUREMENT SITE
- ▼ SEDIMENT-MEASUREMENT SITE

STATION NUMBERS ARE IN ABBREVIATED FORM:
THE FIRST TWO DIGITS ARE OMITTED, FOR EXAMPLE
STATION NUMBER 01176000 IS SHOWN ABOVE AS 176000

	US Army Corps of Engineers New England Division Waltham, Massachusetts
OCTOBER 1996 FLOOD REGIONAL ANALYSIS	
APPROXIMATE RETURN INTERVAL LIMITS OF OCTOBER 1996 PEAK DISCHARGES	
WMS	MAY 1997

APPENDIX A

**STATEMENT OF WORK
MISSION ASSIGNMENT
U.S. ARMY CORPS OF ENGINEERS, NEW ENGLAND DISTRICT
FEMA-1142-DR-MASSACHUSETTS**

STATEMENT OF WORK
Mission Assignment
U.S. Army Corps of Engineers, New England Division
FEMA-1142-DR-Massachusetts

Task Summary: Locate, flag, determine the elevations of, and geo-code into a geographic information system (GIS) compatible database acceptable to FEMA, high water marks from the October 20-21, 1996 storm event. Determine the return frequency of the event at specified rivers.

Justification: Having an historical perspective for the peak elevations, locations of high water, and frequency of return for the water elevations will allow FEMA mitigation employees and community officials to locate development above potential flood damages. The benefit/cost of mitigation projects can be calculated.

Deliverable Items: The Corps of Engineers will:

1. Locate and flag sufficient high water marks to adequately document the storm event and produce the information required under this mission assignment:
 - a) Shawsheen River
 - b) Spicket River
 - c) Aberjona River
 - d) Neponset River
 - e) Lamprey River
 - f) Little River
 - g) Alewife Brook
2. Survey elevations of high water marks to the National Geodetic Vertical Datum. This information will be obtained as soon as possible depending on weather conditions, or by May 1, 1997 at the latest. The elevation of each mark, as well as depth of water at the high water mark elevation and latitude and longitude at each HWM location, shall be recorded. Data will be provided to FEMA in draft form within 2 weeks of completion of field work by the Corps of Engineers.
3. Geo-code (latitude/longitude) each high water mark and the additional data specified in Item 2 in a GIS compatible database format. At the present time FEMA's GIS desktop standard is MapInfo Professional.

Cost of 1,2 and 3 = \$37,500

4. Perform frequency analysis for the October 1996 event for each watercourse specified above in Item 1.
 - a) Evaluate rainfall frequencies at key locations for the specified river watersheds.
 - b) Compute discharge frequencies at pertinent river gaging stations throughout the region with consideration of the rainfall frequency analysis. There are an estimated 15-20 gaging stations this task would utilize located from south coastal Massachusetts to southern Maine.
 - c) Analyze surveyed high water mark data, flood profiles, etc., and estimate peak discharge for the October rainfall and flood event for the specified streams.
 - d) All work on this item should be complete no later than May 1, 1997.

Cost = \$50,000

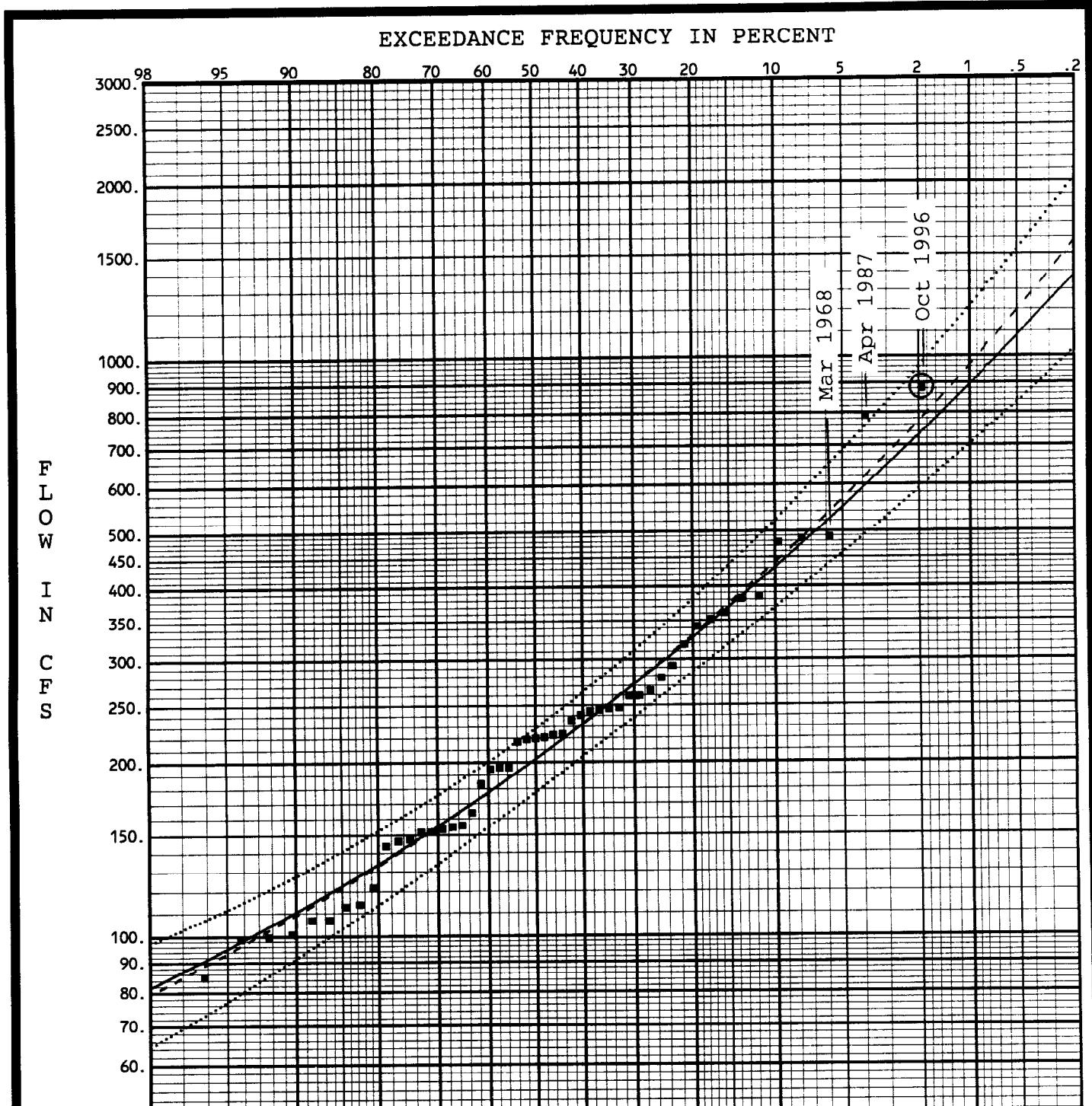
5. Reporting will include, but is not limited to
 - a) Tables providing the high water mark elevations, lat/long and depth of flooding;
 - b) Table comparing existing Flood Insurance Study (FIS) elevations with measured high water mark elevations at each locations. Alternately the high water marks can be plotted on the existing profile from the FIS;
 - c) Frequency analysis results for each studied stream.

All reports will be provided to FEMA in draft form within 30 days of completion of work as described under number above. FEMA will comment on the draft reports within 15 days of receipt. Final reports will be provided to FEMA within 30 days of submission of FEMA's comments on the draft reports.

Total Cost = \$87,500

APPENDIX B

FLOOD FLOW FREQUENCY CURVES

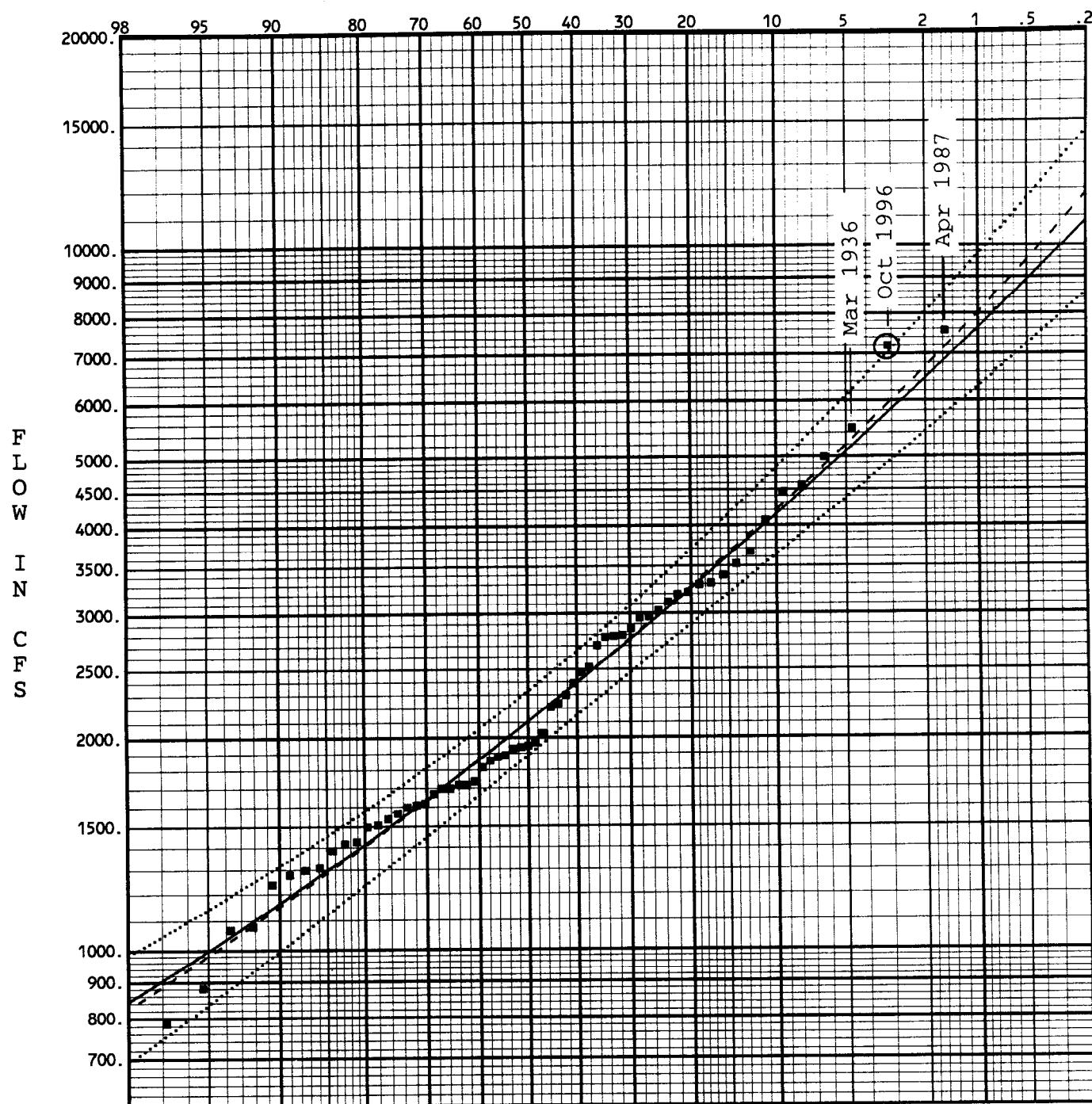


- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS		NUMBER OF EVENTS
LOG TRANSFORM OF FLOW, CFS		
MEAN	2.3262	HISTORIC EVENTS 0
STANDARD DEV	.2331	HIGH OUTLIERS 0
SKEW	.4437	LOW OUTLIERS 0
REGIONAL SKEW	.6000	ZERO OR MISSING 0
ADOPTED SKEW	.5000	SYSTEMATIC EVENTS 51

PARKER RIVER AT BYFIELD, MA
BASIN AREA = 21.3 SQ. MI.
WATER YEARS IN RECORD
1946-1995, 1997

EXCEEDANCE FREQUENCY IN PERCENT



- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS

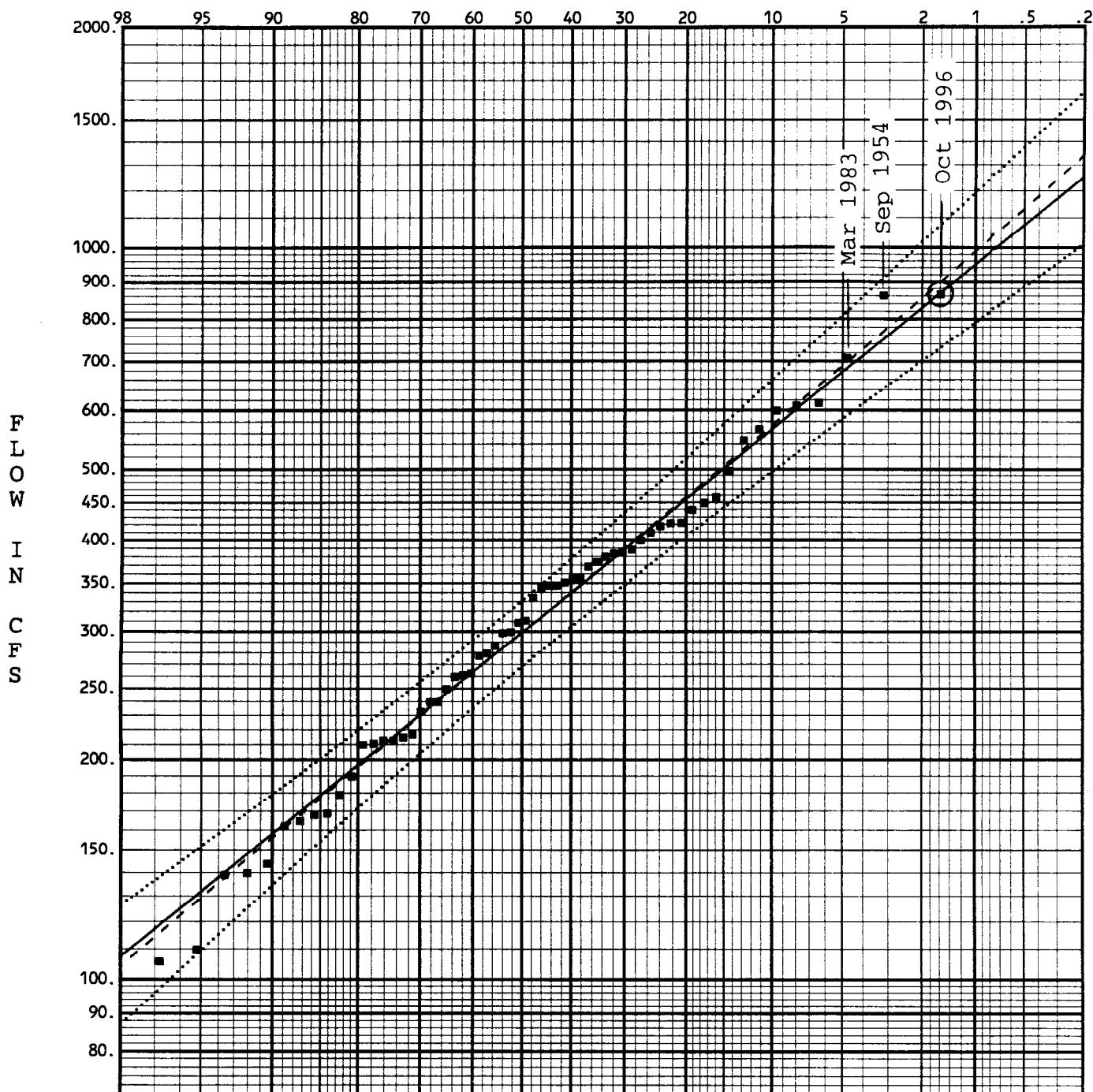
LOG TRANSFORM OF FLOW, CFS

NUMBER OF EVENTS

MEAN	3.3347	HISTORIC EVENTS	0
STANDARD DEV	.2158	HIGH OUTLIERS	0
SKEW	.2603	LOW OUTLIERS	0
REGIONAL SKEW	.5000	ZERO OR MISSING	0
ADOPTED SKEW	.3000	SYSTEMATIC EVENTS	63

LAMPREY RIVER NEAR NEWMARKET
BASIN AREA = 183 SQ. MI.
WATER YEARS IN RECORD
1935-1997

EXCEEDANCE FREQUENCY IN PERCENT



- FLOW Frequency (without Exp. Prob.)
- FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS

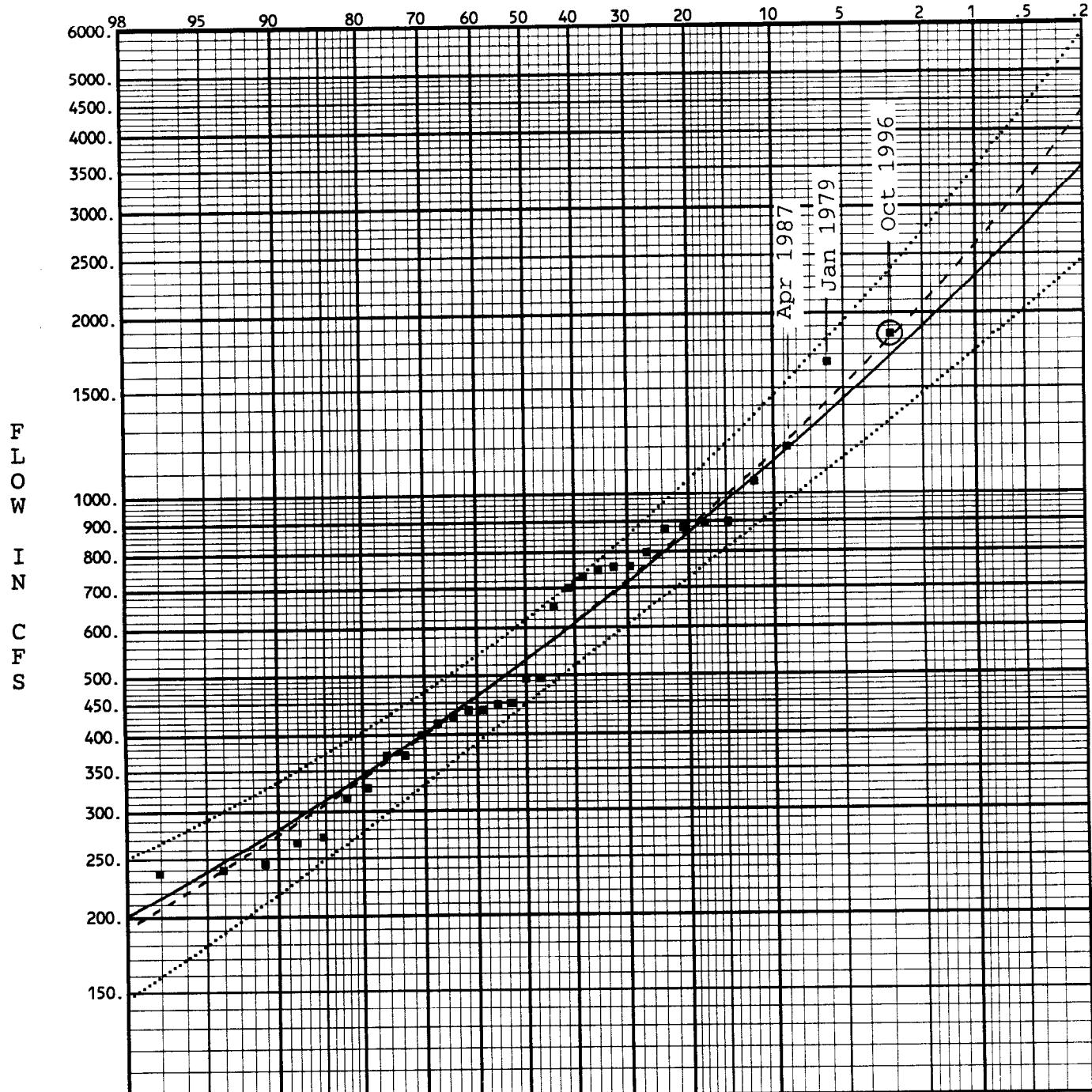
LOG TRANSFORM OF FLOW, CFS

NUMBER OF EVENTS

MEAN	2.4758	HISTORIC EVENTS	0
STANDARD DEV	.2159	HIGH OUTLIERS	0
SKEW	-.1666	LOW OUTLIERS	0
REGIONAL SKEW	.5000	ZERO OR MISSING	0
ADOPTED SKEW	.0000	SYSTEMATIC EVENTS	62

OYSTER RIVER NEAR DURHAM, NH
BASIN AREA = 12.1 SQ. MI.
WATER YEARS IN RECORD
1935-1995, 1997

EXCEEDANCE FREQUENCY IN PERCENT

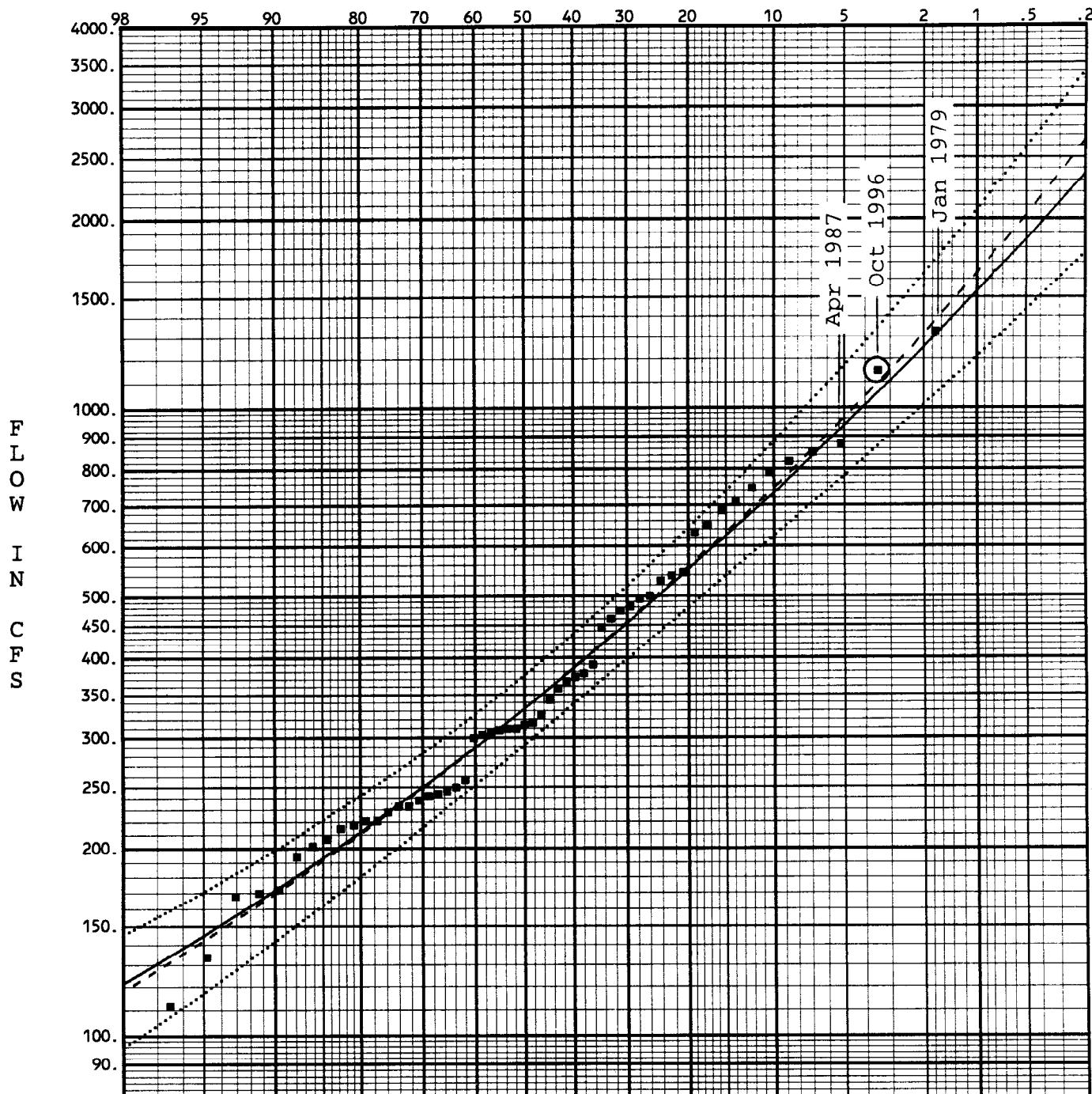


- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS		NUMBER OF EVENTS	
LOG TRANSFORM OF FLOW, CFS			
MEAN	2.7406	HISTORIC EVENTS	0
STANDARD DEV	.2384	HIGH OUTLIERS	0
SKEW	.3095	LOW OUTLIERS	0
REGIONAL SKEW	.6000	ZERO OR MISSING	0
ADOPTED SKEW	.4000	SYSTEMATIC EVENTS	33

SHAWSHEEN RIVER NEAR WILMINGT
BASIN AREA = 36.5 SQ. MI.
WATER YEARS IN RECORD
1964-1995, 1997

EXCEEDANCE FREQUENCY IN PERCENT

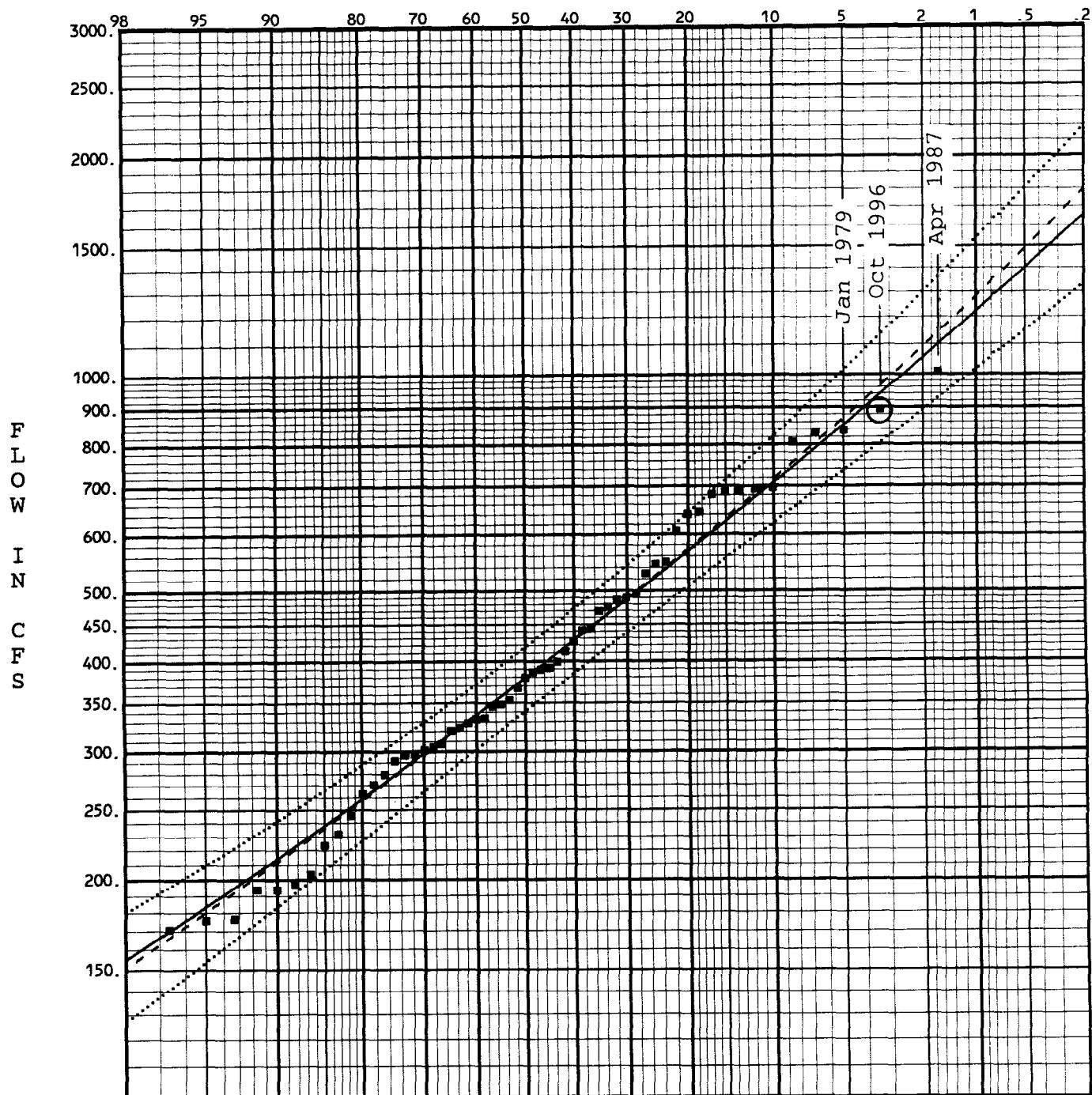


- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS		NUMBER OF EVENTS
LOG TRANSFORM OF FLOW, CFS		
MEAN	2.5387	HISTORIC EVENTS 0
STANDARD DEV	.2476	HIGH OUTLIERS 0
SKW	.2450	LOW OUTLIERS 0
REGIONAL SKW	.7000	ZERO OR MISSING 0
ADOPTED SKW	.4000	SYSTEMATIC EVENTS 57

ABERJONA RIVER AT WINCHESTER
 BASIN AREA = 24.1 SQ MI
 WATER YEARS IN RECORD
 1940-1995, 1997

EXCEEDANCE FREQUENCY IN PERCENT



- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS

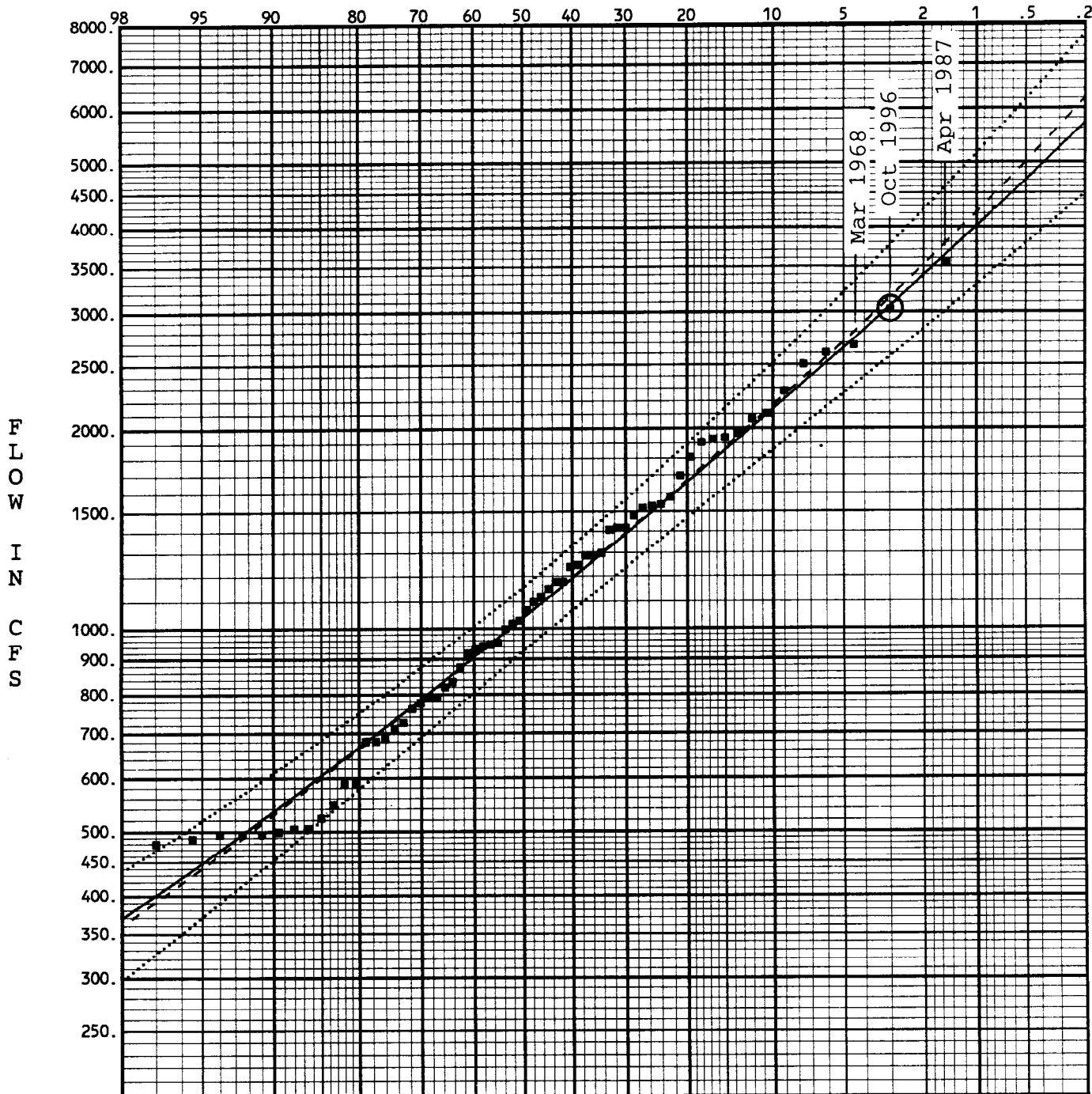
LOG TRANSFORM OF FLOW, CFS

NUMBER OF EVENTS

MEAN	2.5859	HISTORIC EVENTS	0
STANDARD DEV	.2030	HIGH OUTLIERS	0
SKEW	.0476	LOW OUTLIERS	0
REGIONAL SKEW	.7000	ZERO OR MISSING	0
ADOPTED SKEW	.2000	SYSTEMATIC EVENTS	59

IPSWICH RIVER AT S. MIDDLETON
BASIN AREA = 44.5 SQ. MI.
WATER YEARS IN RECORD
1938-1995, 1997

EXCEEDANCE FREQUENCY IN PERCENT



- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

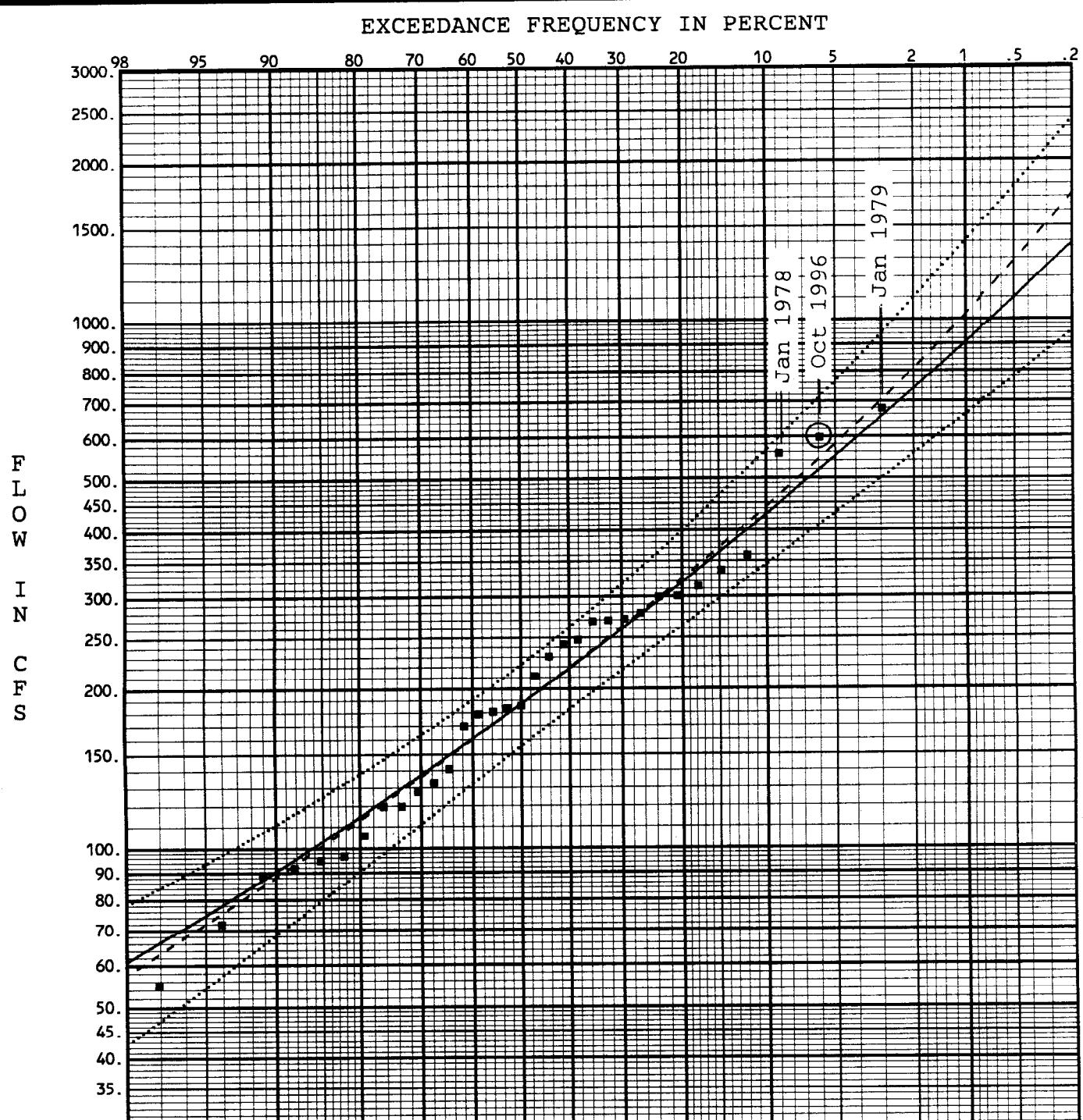
FREQUENCY STATISTICS

LOG TRANSFORM OF FLOW, CFS

NUMBER OF EVENTS

MEAN	3.0245	HISTORIC EVENTS	0
STANDARD DEV	.2348	HIGH OUTLIERS	0
SKW	.0502	LOW OUTLIERS	0
REGIONAL SKW	.7000	ZERO OR MISSING	0
ADOPTED SKW	.2000	SYSTEMATIC EVENTS	66

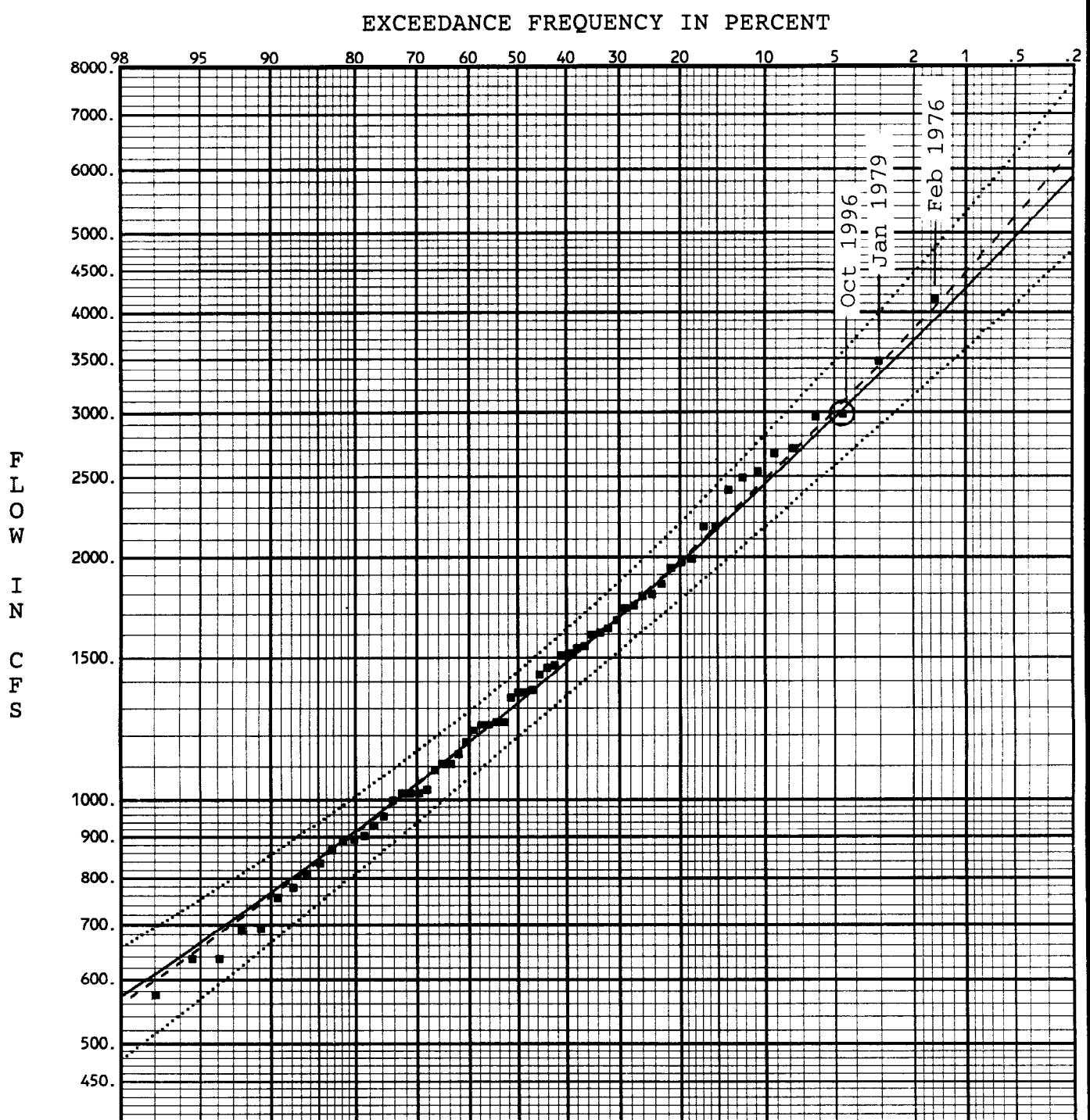
IPSWICH RIVER NEAR IPSWICH, MA
BASIN AREA = 125.0 SQ. MI.
WATER YEARS IN RECORD
1931-1995, 1997



- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS		NUMBER OF EVENTS	
LOG TRANSFORM OF FLOW, CFS			
MEAN	2.2854	HISTORIC EVENTS	0
STANDARD DEV	.2645	HIGH OUTLIERS	0
SKEW	.0710	LOW OUTLIERS	0
REGIONAL SKEW	.6000	ZERO OR MISSING	0
ADOPTED SKEW	.3000	SYSTEMATIC EVENTS	33

NASHOBA BROOK NEAR ACTON, MA
BASIN AREA = 12.8 SQ.MI.
WATER YEARS IN RECORD
1964-1995, 1997

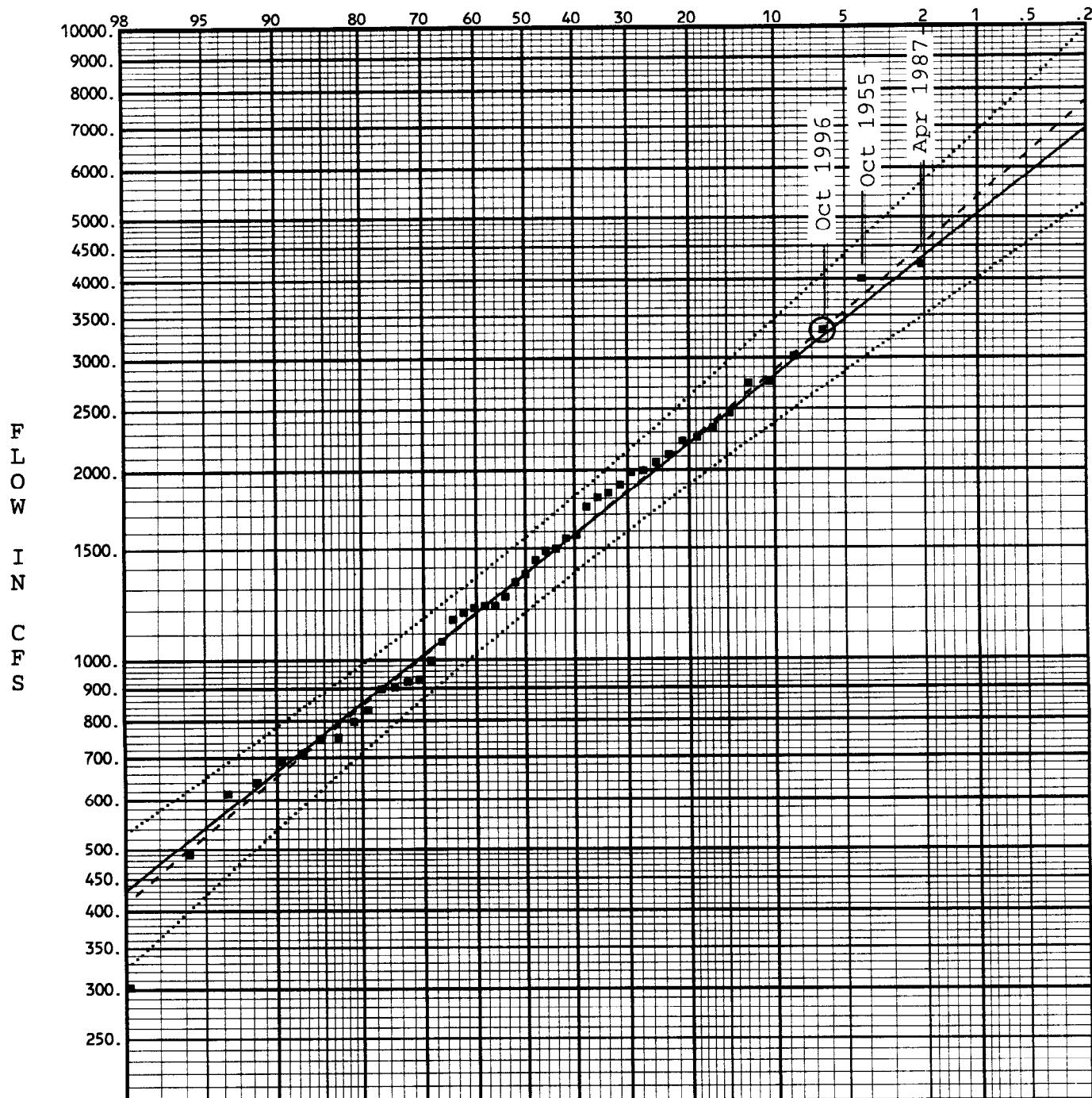


- FLOW Frequency (without Exp. Prob.)
- FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS		NUMBER OF EVENTS	
LOG TRANSFORM OF FLOW, CFS			
MEAN	3.1303	HISTORIC EVENTS	0
STANDARD DEV	.1971	HIGH OUTLIERS	0
SKW	.2089	LOW OUTLIERS	0
REGIONAL SKW	.7000	ZERO OR MISSING	0
ADOPTED SKW	.3000	SYSTEMATIC EVENTS	65

CHARLES RIVER AT WALTHAM, MA
BASIN AREA = 251.0 SQ. MI.
WATER YEARS IN RECORD
1932-1995, 1997

EXCEEDANCE FREQUENCY IN PERCENT



- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS

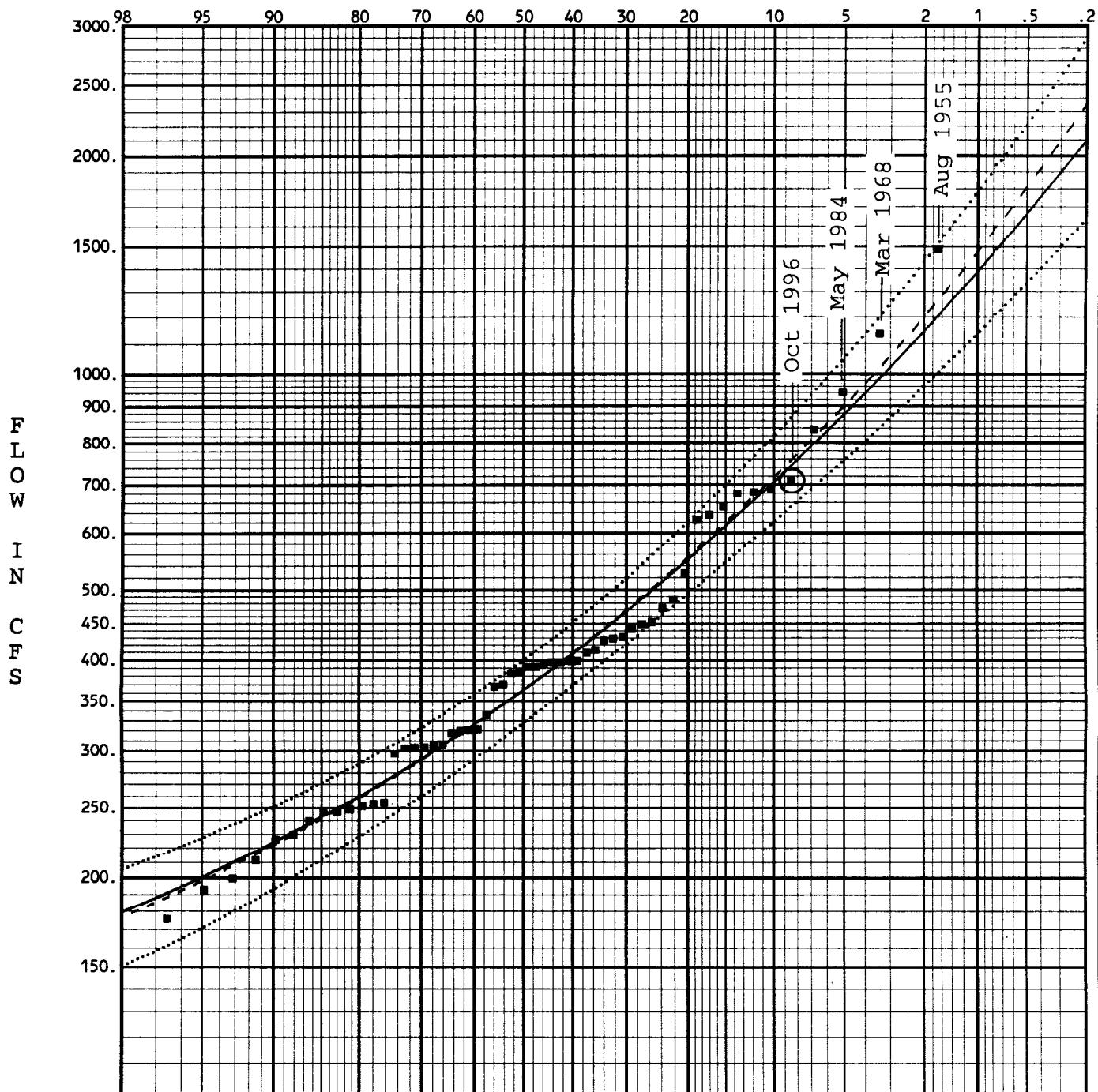
LOG TRANSFORM OF FLOW, CFS

NUMBER OF EVENTS

MEAN	3.1368	HISTORIC EVENTS	0
STANDARD DEV	.2444	HIGH OUTLIERS	0
SKW	-.2044	LOW OUTLIERS	0
REGIONAL SKW	.6000	ZERO OR MISSING	0
ADOPTED SKW	.0000	SYSTEMATIC EVENTS	47

SQUANNACOOK RIVER
BASIN AREA = 65.9 SQ. MI.
WATER YEARS IN RECORD
1950-1995, 1997

EXCEEDANCE FREQUENCY IN PERCENT



- FLOW Frequency (without Exp. Prob.)
- FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS

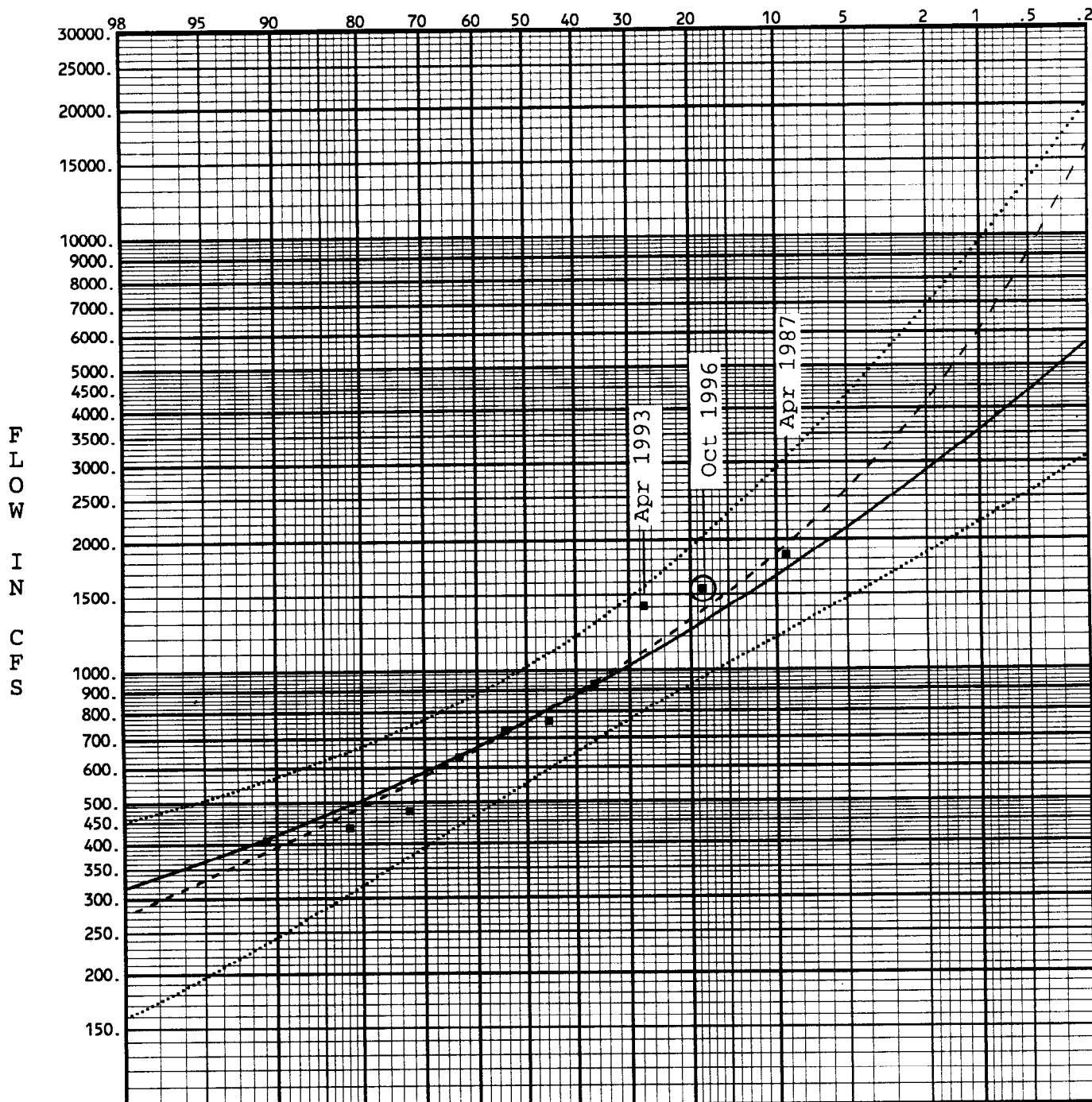
LOG TRANSFORM OF FLOW, CFS

NUMBER OF EVENTS

MEAN	2.5840	HISTORIC EVENTS	0
STANDARD DEV	.1980	HIGH OUTLIERS	0
SKEW	.6593	LOW OUTLIERS	0
REGIONAL SKEW	.7000	ZERO OR MISSING	0
ADOPTED SKEW	.7000	SYSTEMATIC EVENTS	58

NEPONSET RIVER AT NORWOOD, MA
BASIN AREA = 34.7 SQ. MI.
WATER YEARS IN RECORD
1938, 1940-1995, 1997

EXCEEDANCE FREQUENCY IN PERCENT

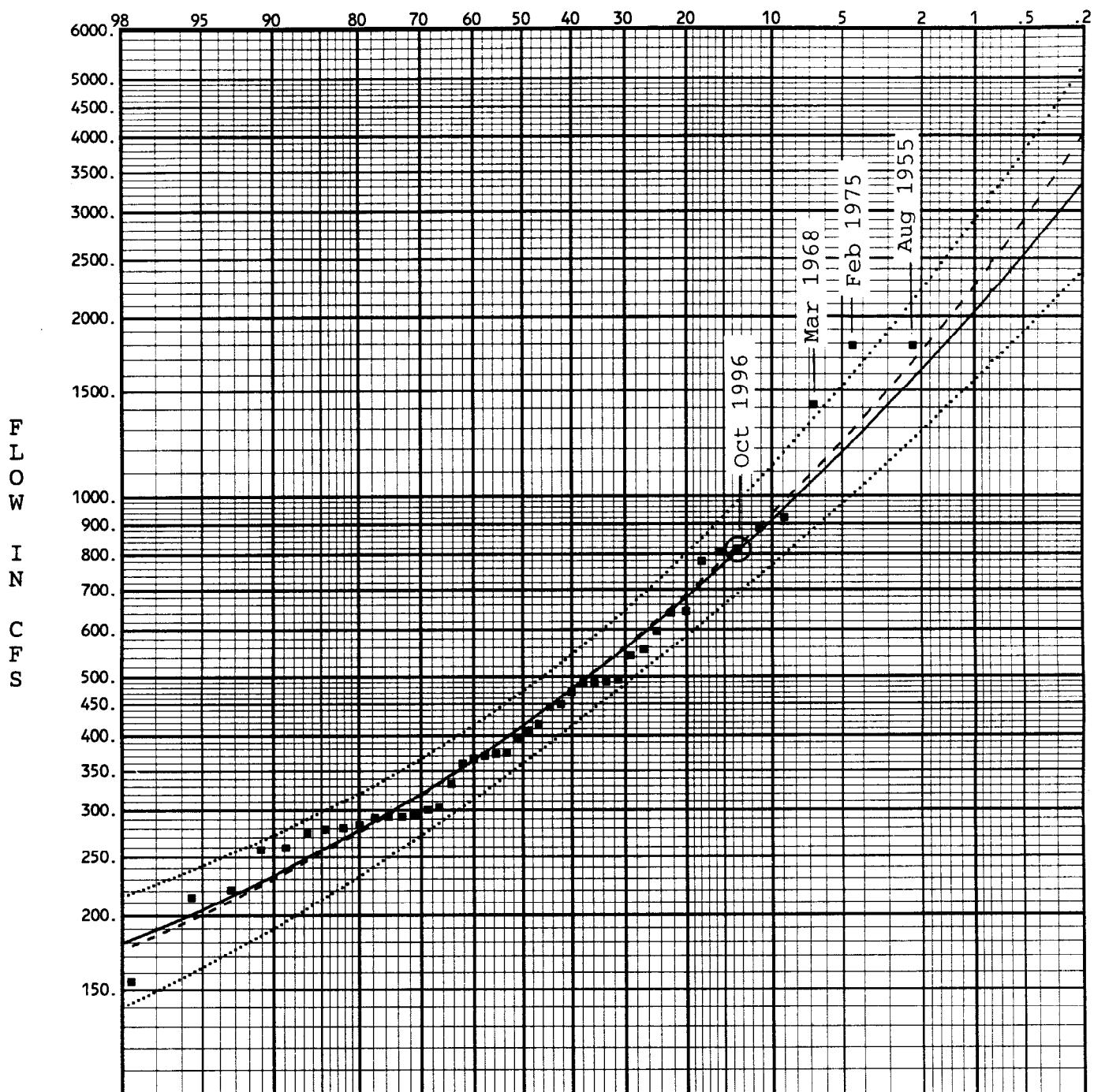


- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS		NUMBER OF EVENTS
LOG TRANSFORM OF FLOW, CFS		
MEAN	2.9055	HISTORIC EVENTS 0
STANDARD DEV	.2348	HIGH OUTLIERS 0
SKEW	.3038	LOW OUTLIERS 0
REGIONAL SKEW	.6000	ZERO OR MISSING 0
ADOPTED SKEW	.6000	SYSTEMATIC EVENTS 10

BEAVER BROOK AT N. PELHAM, MA
BASIN AREA = 47.8 SQ. MI.
WATER YEARS IN RECORD
1987-1989, 1991-1997

EXCEEDANCE FREQUENCY IN PERCENT

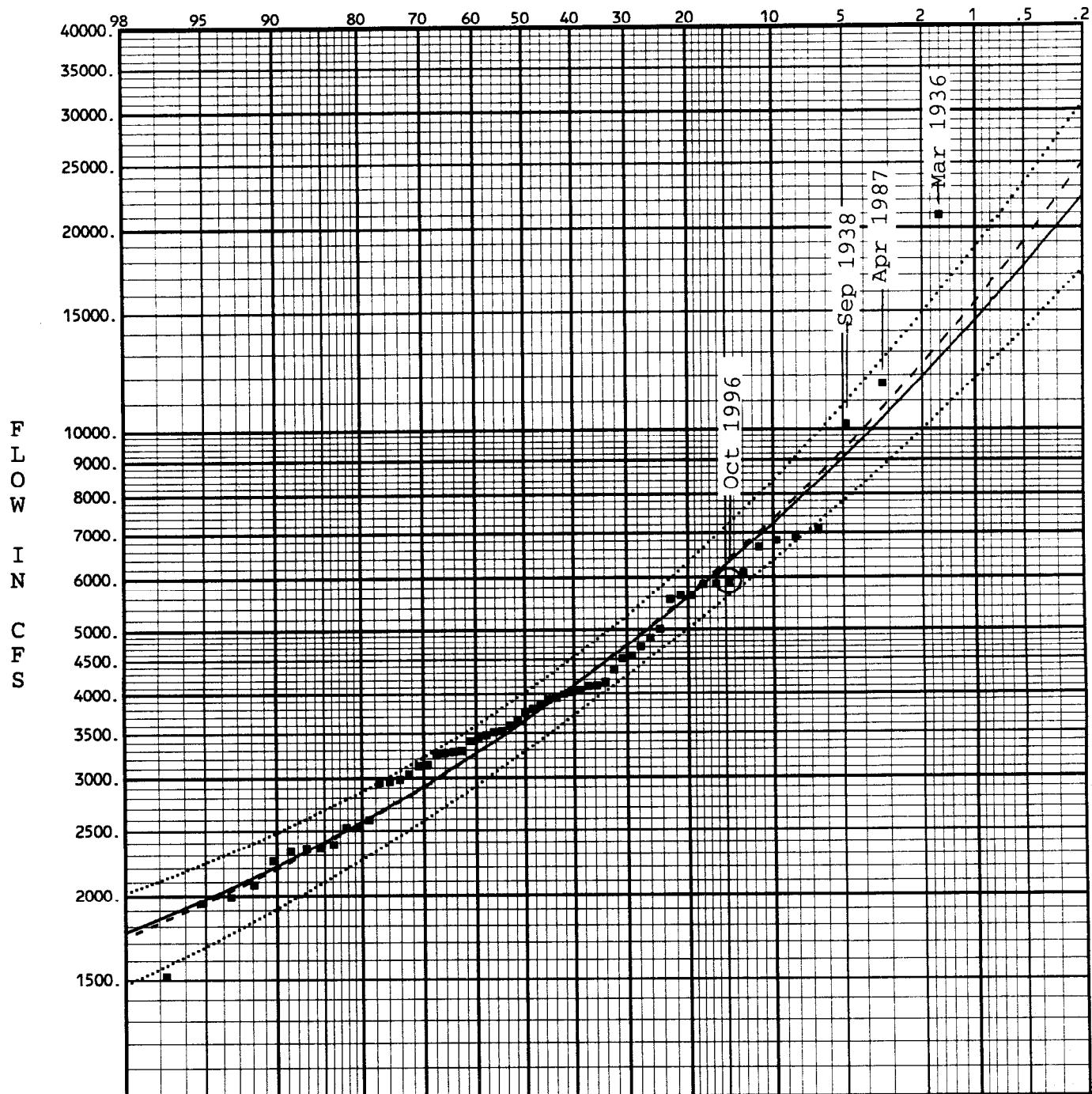


- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS		NUMBER OF EVENTS	
LOG TRANSFORM OF FLOW, CFS			
MEAN	2.6456	HISTORIC EVENTS	0
STANDARD DEV	.2352	HIGH OUTLIERS	0
SKW	.8578	LOW OUTLIERS	0
REGIONAL SKW	.7000	ZERO OR MISSING	0
ADOPTED SKW	.7000	SYSTEMATIC EVENTS	44

E.BRANCH NEPONSET RIVER
BASIN AREA = 27.2 SQ. MI.
WATER YEARS IN RECORD
1953-1995, 1997

EXCEEDANCE FREQUENCY IN PERCENT

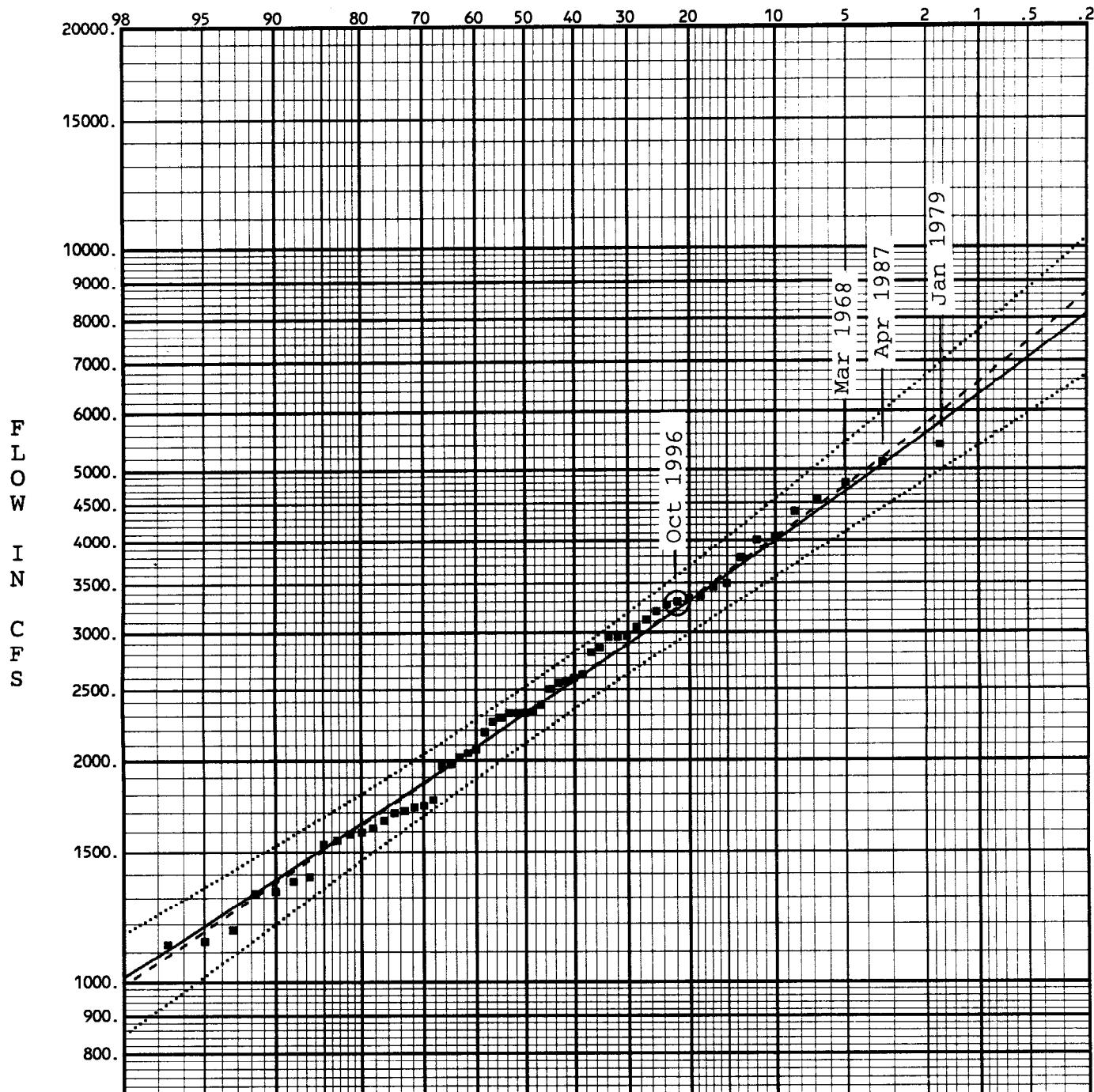


- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS		NUMBER OF EVENTS
LOG TRANSFORM OF FLOW, CFS		
MEAN	3.5864	HISTORIC EVENTS 0
STANDARD DEV	.2042	HIGH OUTLIERS 0
SKEW	.7833	LOW OUTLIERS 0
REGIONAL SKEW	.6000	ZERO OR MISSING 0
ADOPTED SKEW	.7000	SYSTEMATIC EVENTS 61

NASHUA RIVER AT E. PEPPERELL
BASIN AREA = 435.0 SQ. MI.
WATER YEARS IN RECORD
1936-1995, 1997

EXCEEDANCE FREQUENCY IN PERCENT



- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS

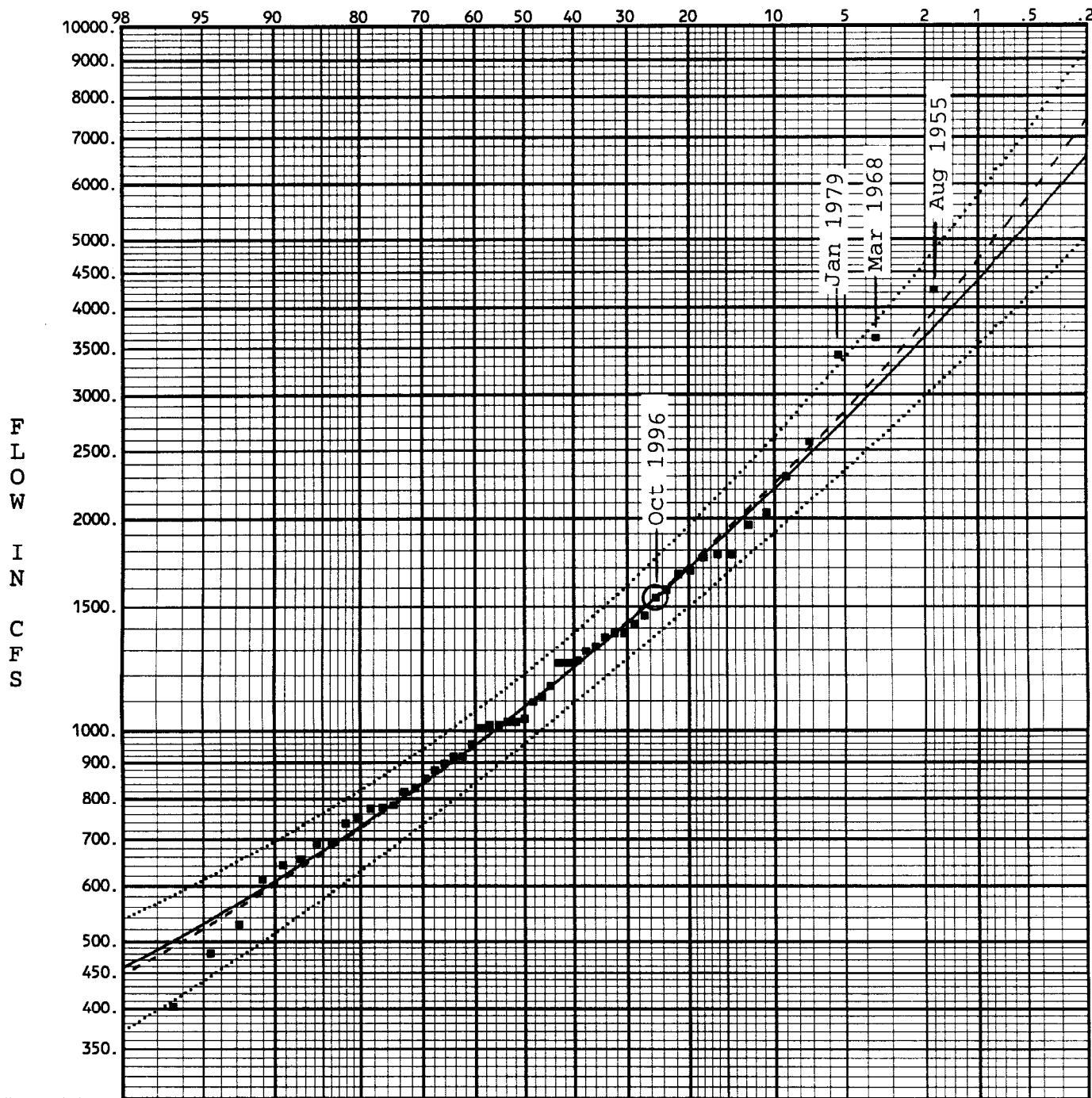
LOG TRANSFORM OF FLOW, CFS

NUMBER OF EVENTS

MEAN	3.3679	HISTORIC EVENTS	0
STANDARD DEV	.1803	HIGH OUTLIERS	0
SKEW	-.0686	LOW OUTLIERS	0
REGIONAL SKEW	.6000	ZERO OR MISSING	0
ADOPTED SKEW	.1000	SYSTEMATIC EVENTS	59

CONCORD RIVER AT LOWELL, MA
BASIN AREA = 400.0 SQ. MI.
WATER YEARS IN RECORD
1938-1995, 1997

EXCEEDANCE FREQUENCY IN PERCENT

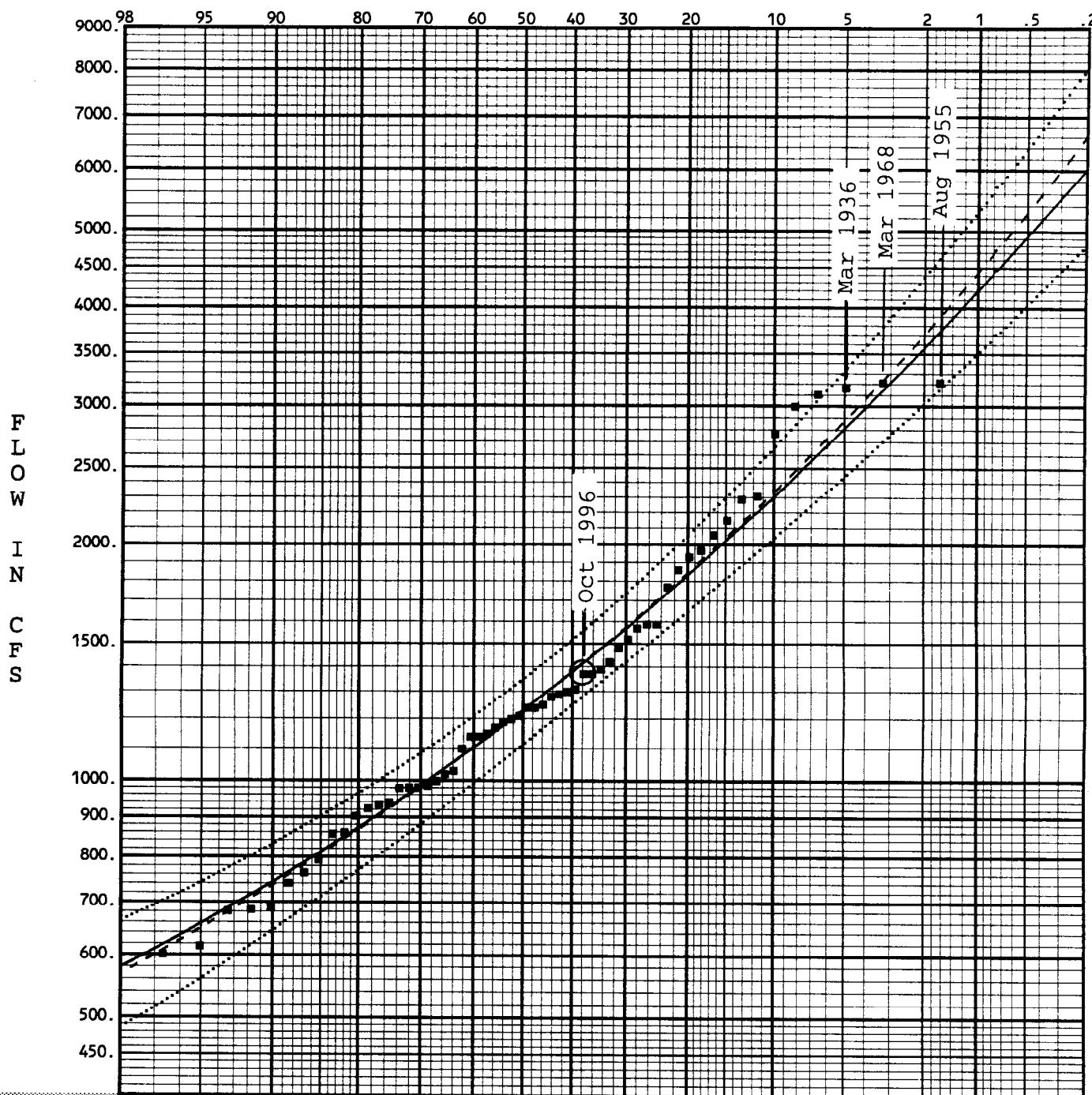


- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS		NUMBER OF EVENTS	
LOG TRANSFORM OF FLOW, CFS			
MEAN	3.0522	HISTORIC EVENTS	0
STANDARD DEV	.2199	HIGH OUTLIERS	0
SKW	.3957	LOW OUTLIERS	0
REGIONAL SKW	.7000	ZERO OR MISSING	0
ADOPTED SKW	.5000	SYSTEMATIC EVENTS	55

ASSABET RIVER AT MAYNARD, MA
BASIN AREA = 116.0 SQ. MI.
WATER YEARS IN RECORD
1942-1995, 1997

EXCEEDANCE FREQUENCY IN PERCENT



- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS

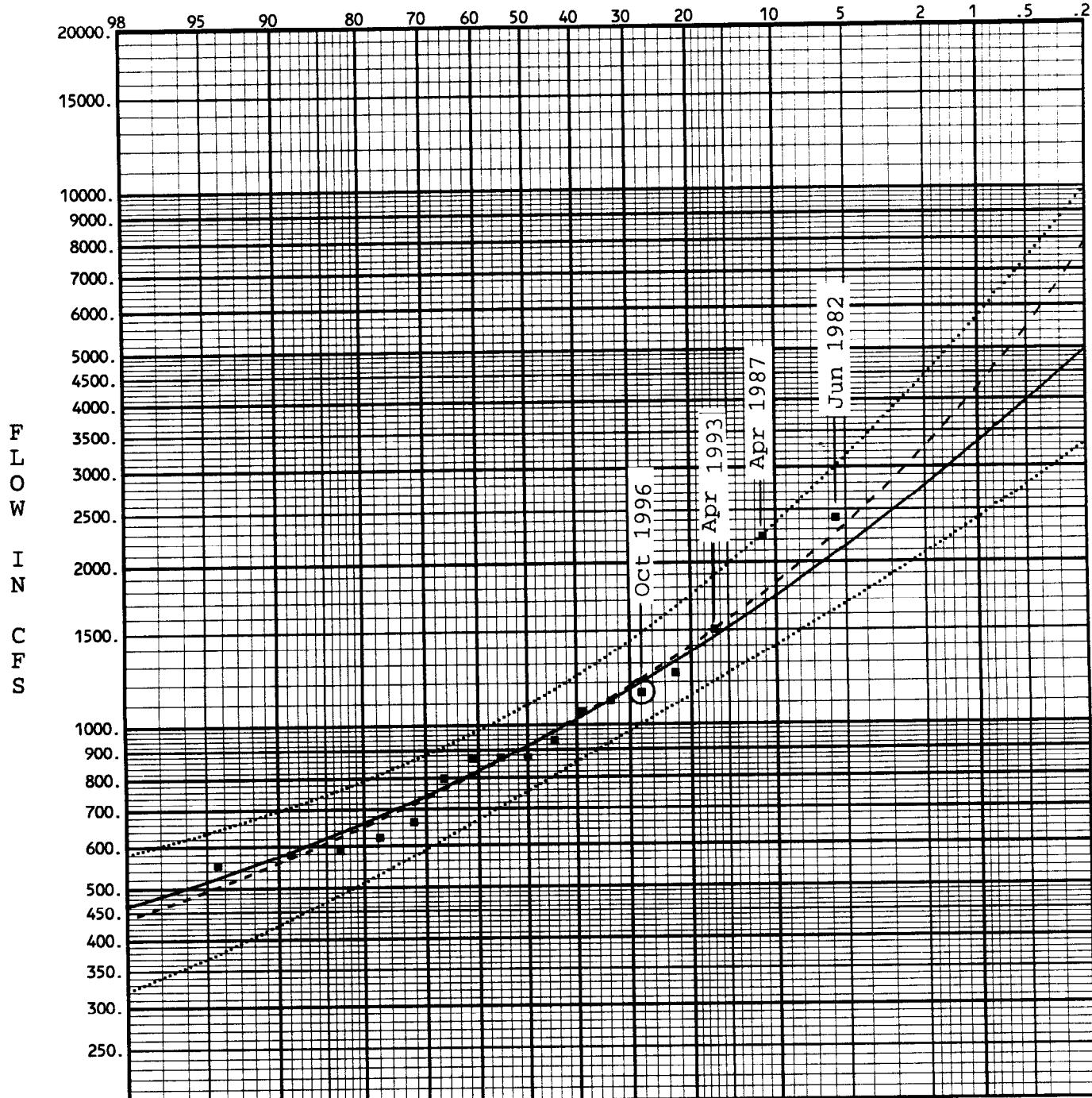
LOG TRANSFORM OF FLOW, CFS

NUMBER OF EVENTS

MEAN	3.1061	HISTORIC EVENTS	0
STANDARD DEV	.1932	HIGH OUTLIERS	0
SKEW	.4310	LOW OUTLIERS	0
REGIONAL SKEW	.7000	ZERO OR MISSING	0
ADOPTED SKEW	.5000	SYSTEMATIC EVENTS	60

CHARLES RIVER AT DOVER, MA
BASIN AREA = 183.0 SQ. MI.
WATER YEARS IN RECORD
1936, 1938-1995, 1997

EXCEEDANCE FREQUENCY IN PERCENT



- FLOW Frequency (without Exp. Prob.)
- - - FLOW Frequency (with Exp. Prob.)
- Weibull Plotting Positions
- 5% and 95% Confidence Limits

FREQUENCY STATISTICS

LOG TRANSFORM OF FLOW, CFS

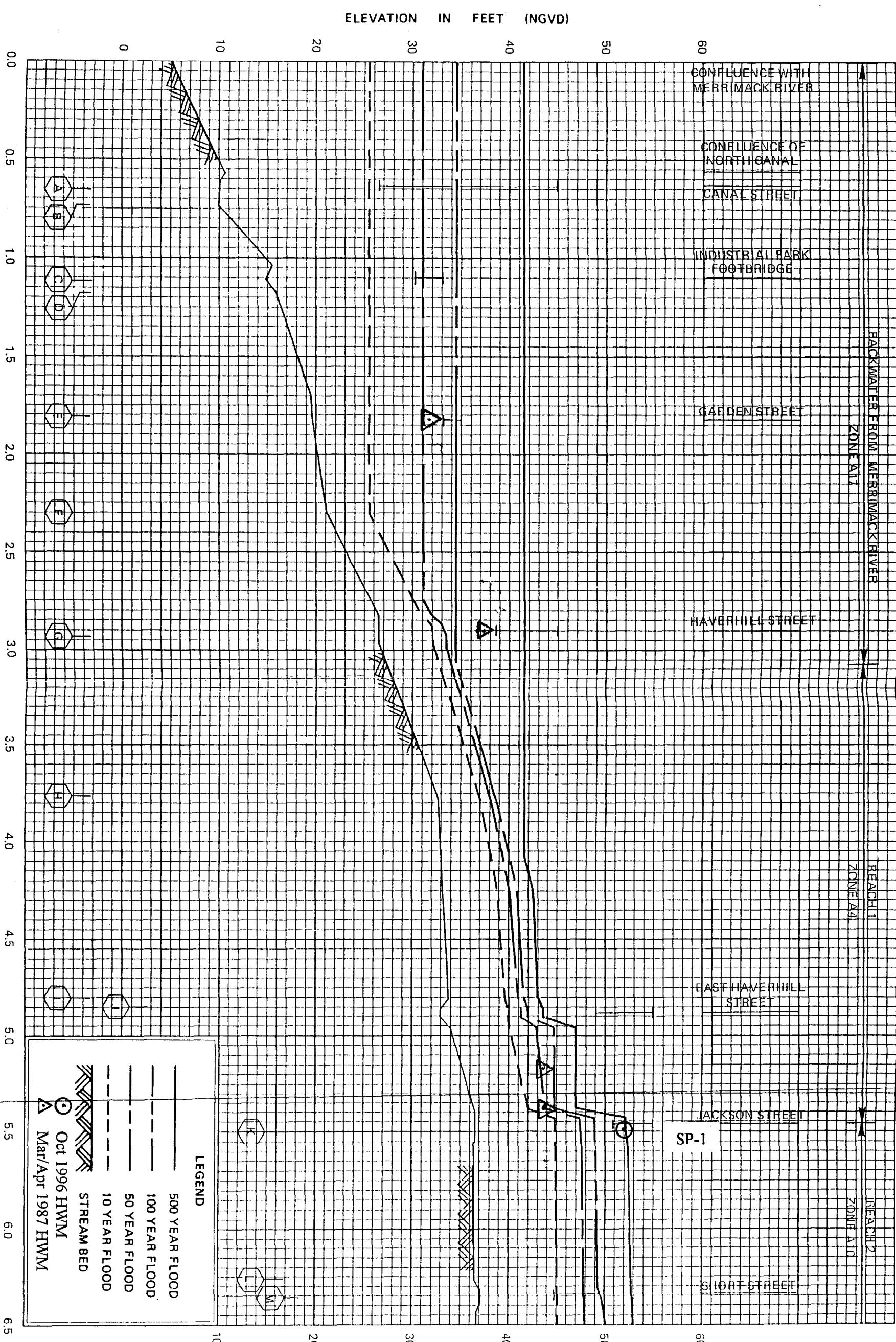
NUMBER OF EVENTS

MEAN	2.9841	HISTORIC EVENTS	0
STANDARD DEV	.1909	HIGH OUTLIERS	0
SKW	.7727	LOW OUTLIERS	0
REGIONAL SKW	.7000	ZERO OR MISSING	0
ADOPTED SKW	.7000	SYSTEMATIC EVENTS	17

SUDBURY RIVER AT SAXONVILLE
BASIN AREA = 106.0 SQ. MI.
WATER YEARS IN RECORD
1980-1995, 1997

APPENDIX C

**EXISTING FLOOD INSURANCE STUDY PROFILES
WITH OCTOBER 1996 HIGH WATER MARKS PLOTTED**

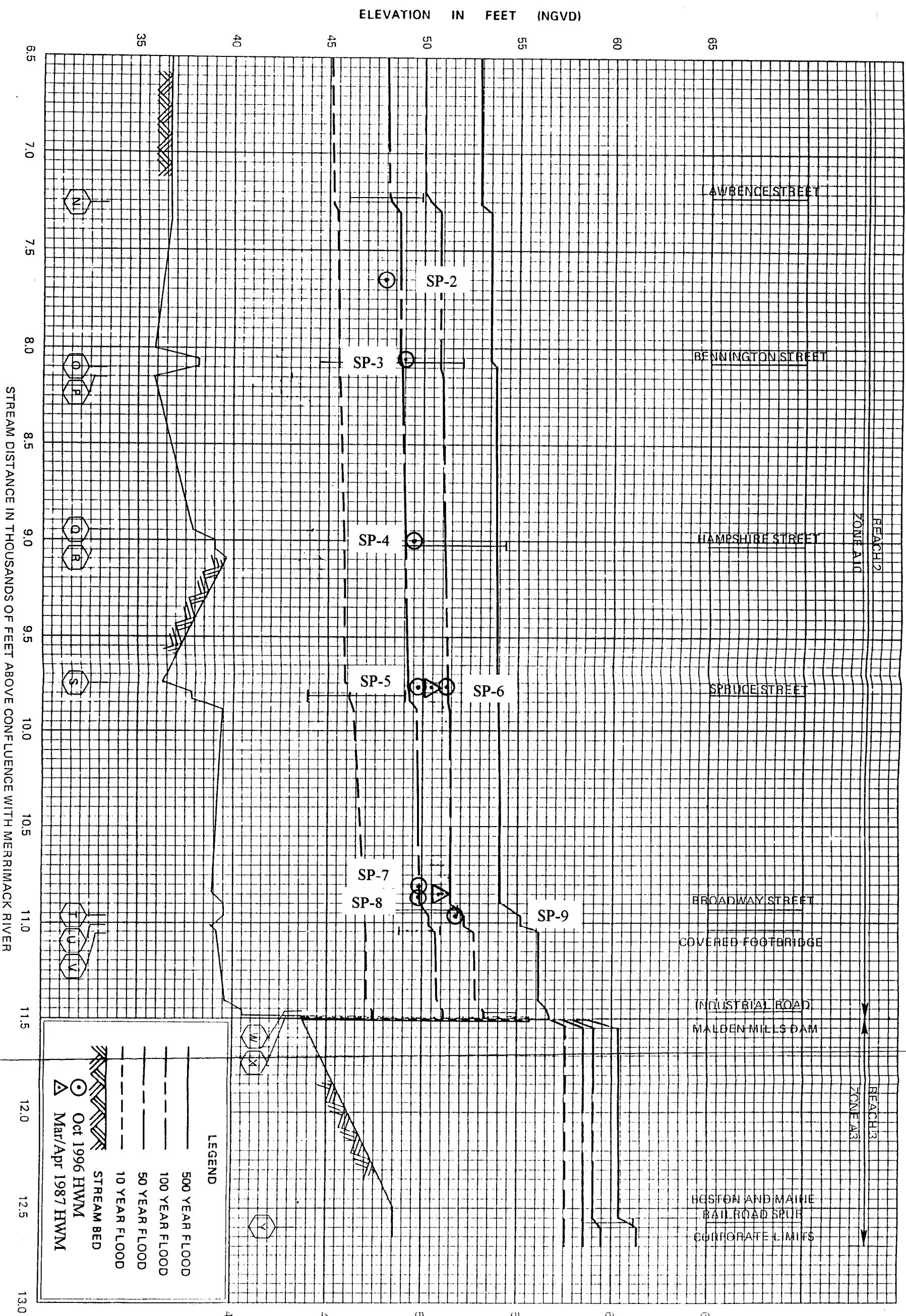


FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LAWRENCE, MA
(ESSEX CO.)

FLOOD PROFILES

SPICKET RIVER

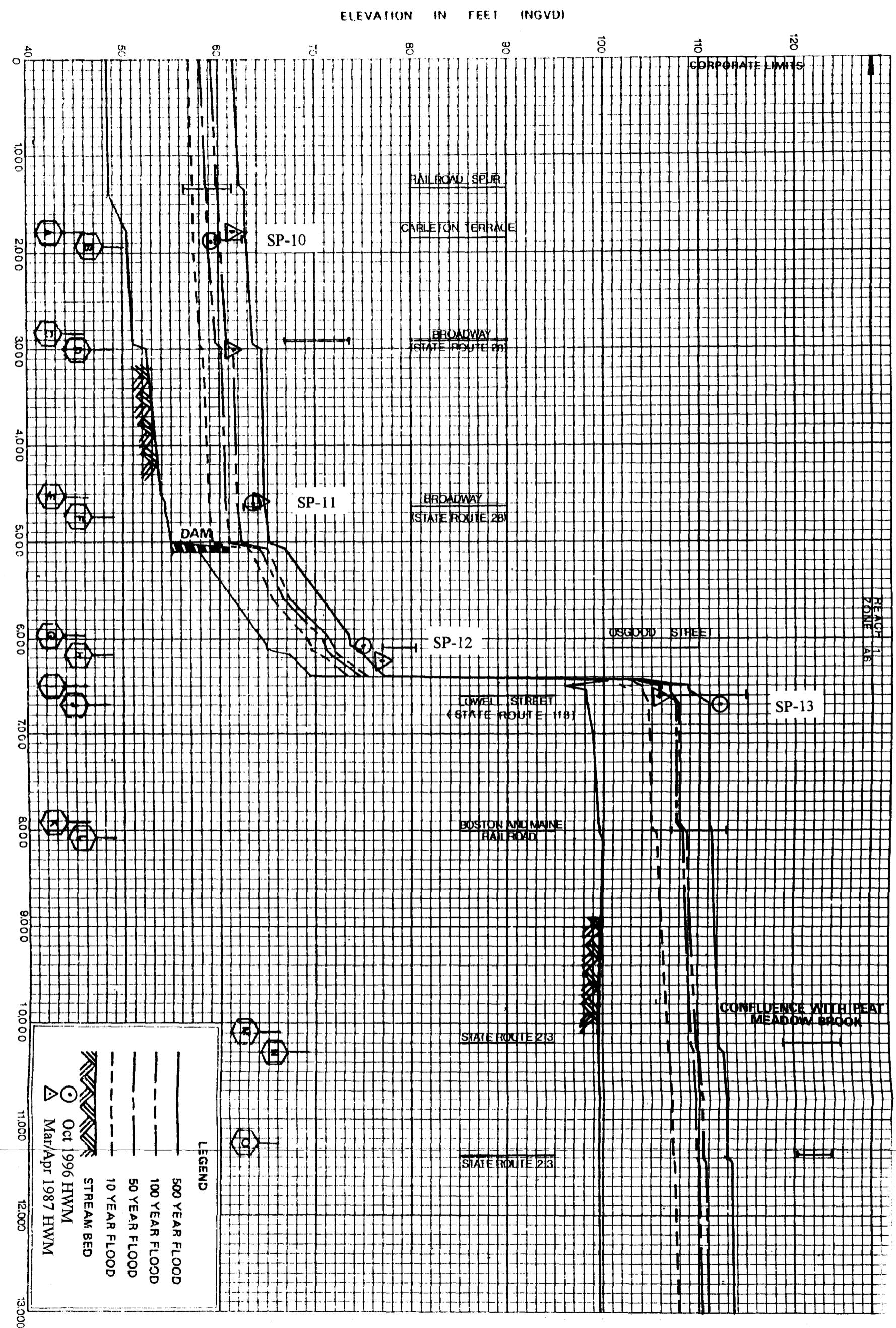


FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LAWRENCE, MA
(ESSEX CO.)

FLOOD PROFILES

SPICKET RIVER

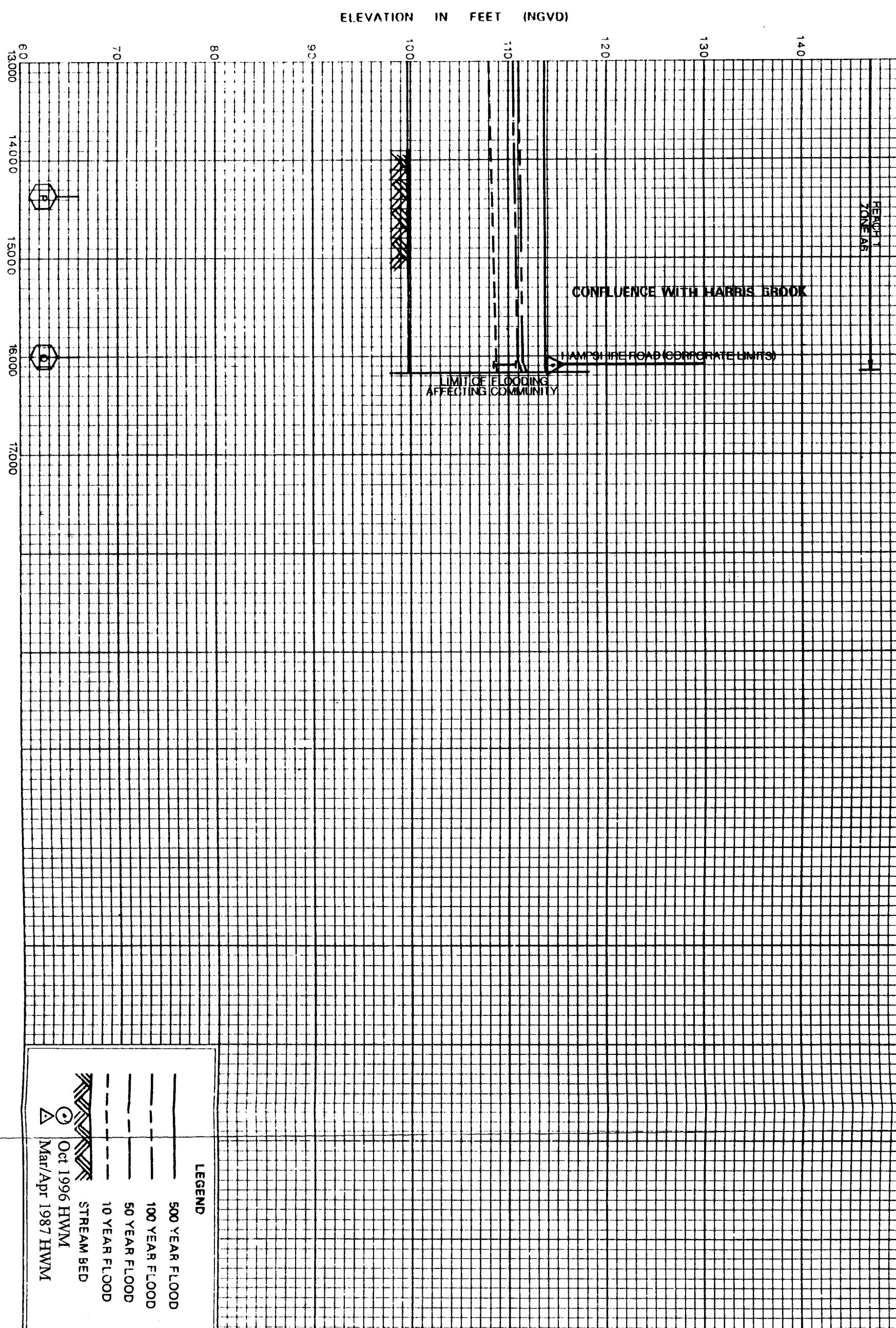


FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF METHUEN, MA
(ESSEX COUNTY)

FLOOD PROFILES

SPICKET RIVER

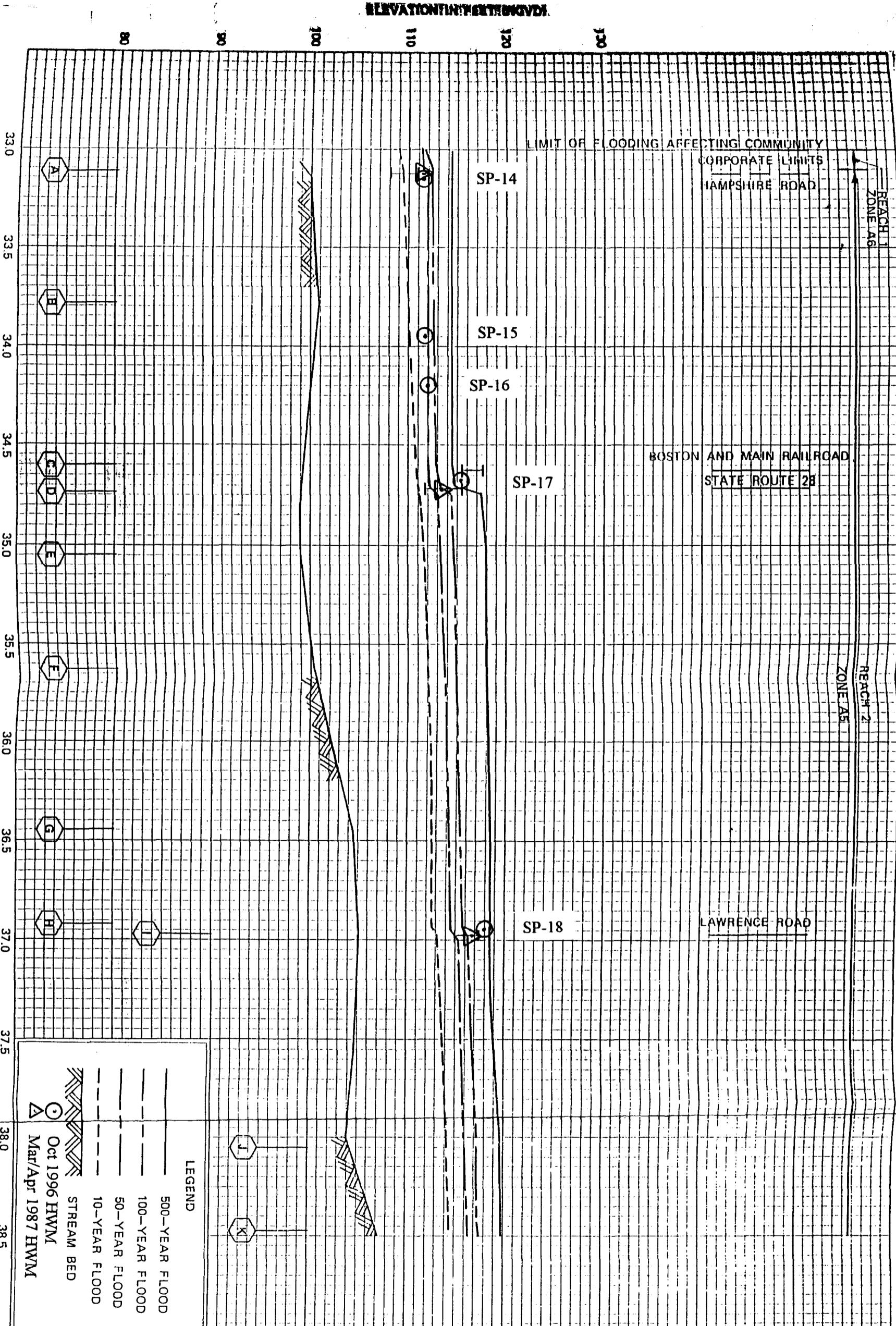


FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF METHUEN, MA
(ESSEX COUNTY)

FLOOD PROFILES

SPICKET RIVER



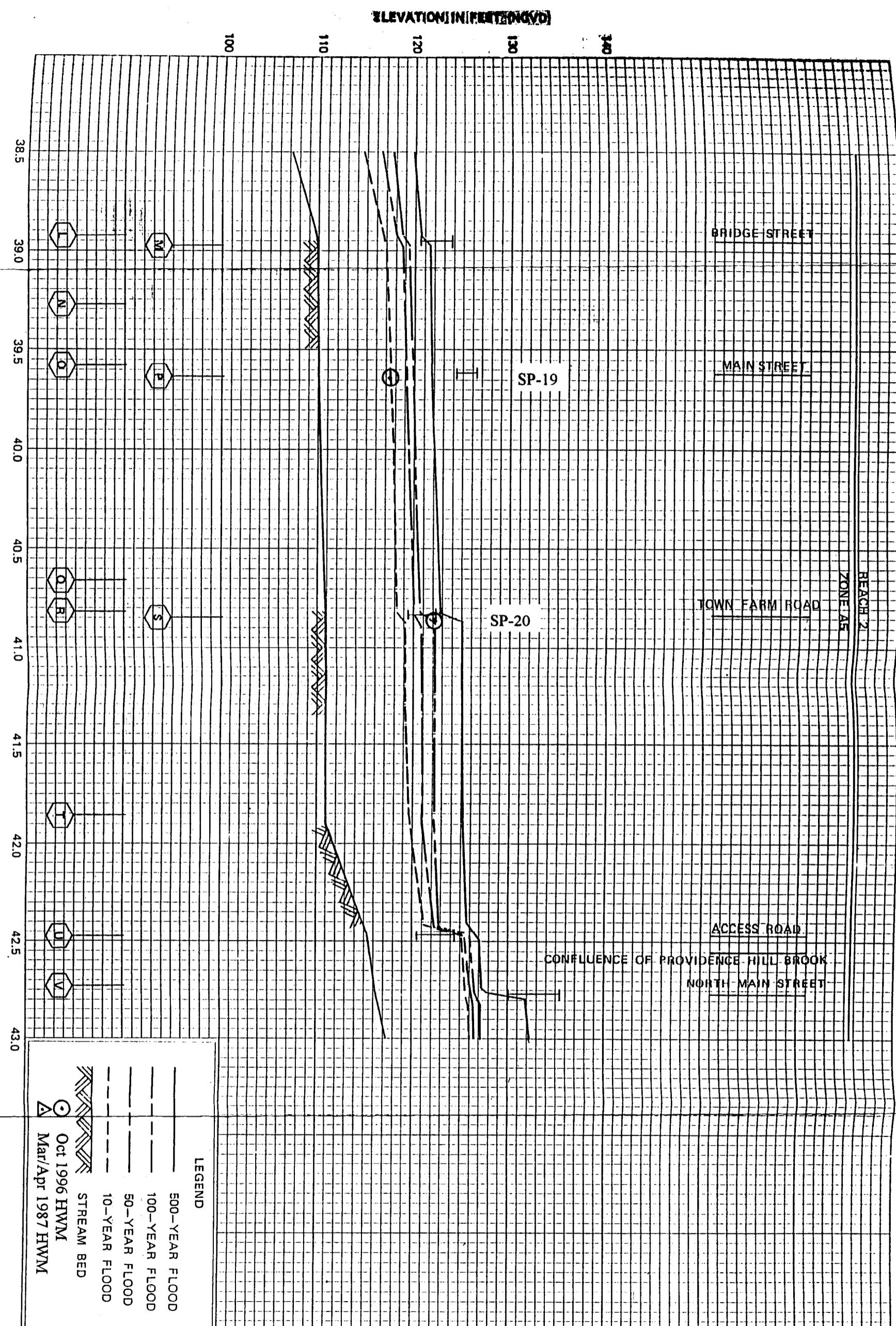
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

Federal Insurance Administration

TOWN OF SALEM, NH
(ROCKINGHAM CO.)

FLOOD PROFILES

SPICKET RIVER



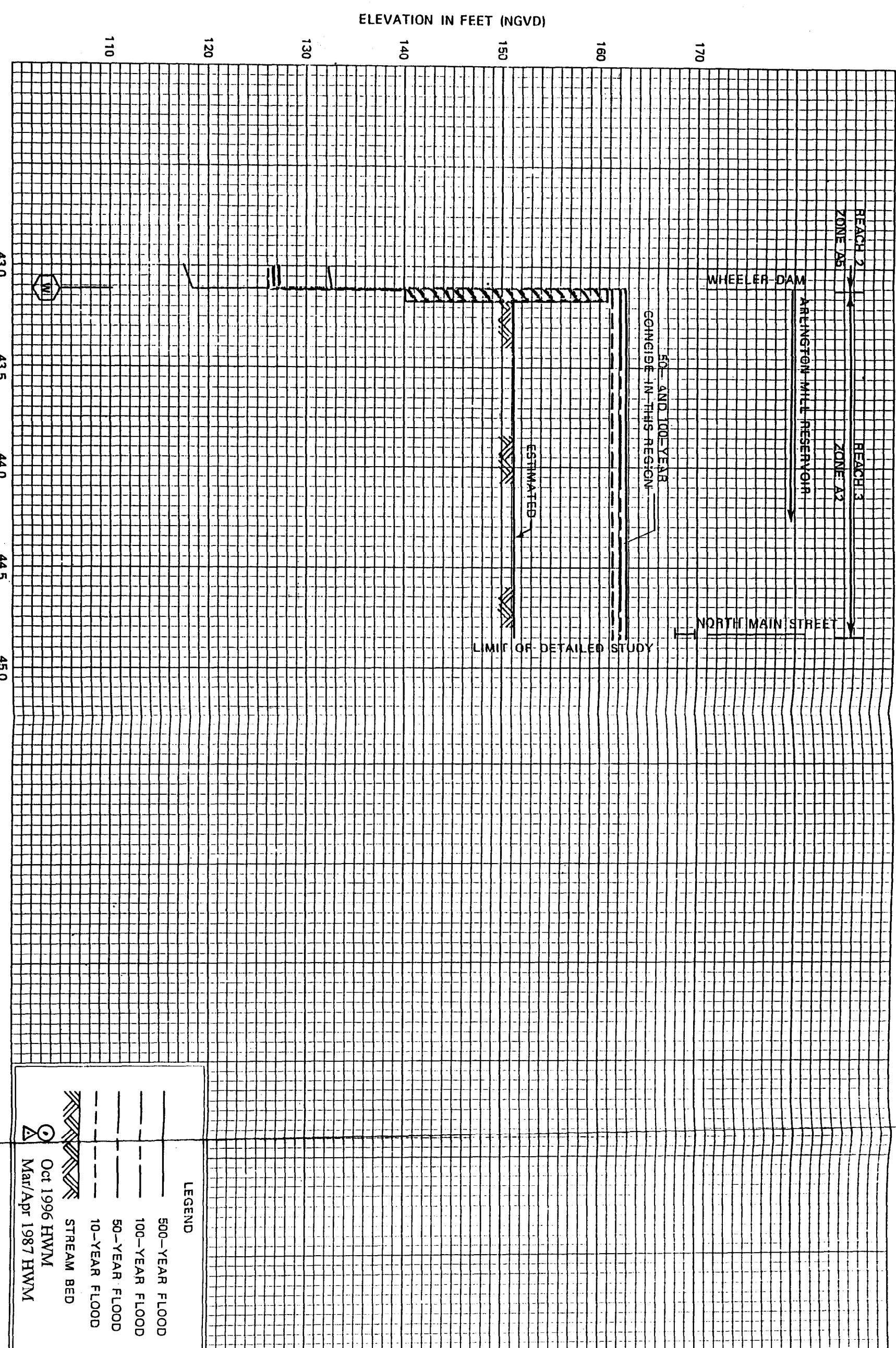
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

Federal Insurance Administration

TOWN OF SALEM, NH
(ROCKINGHAM CO.)

FLOOD PROFILES

SPICKET RIVER

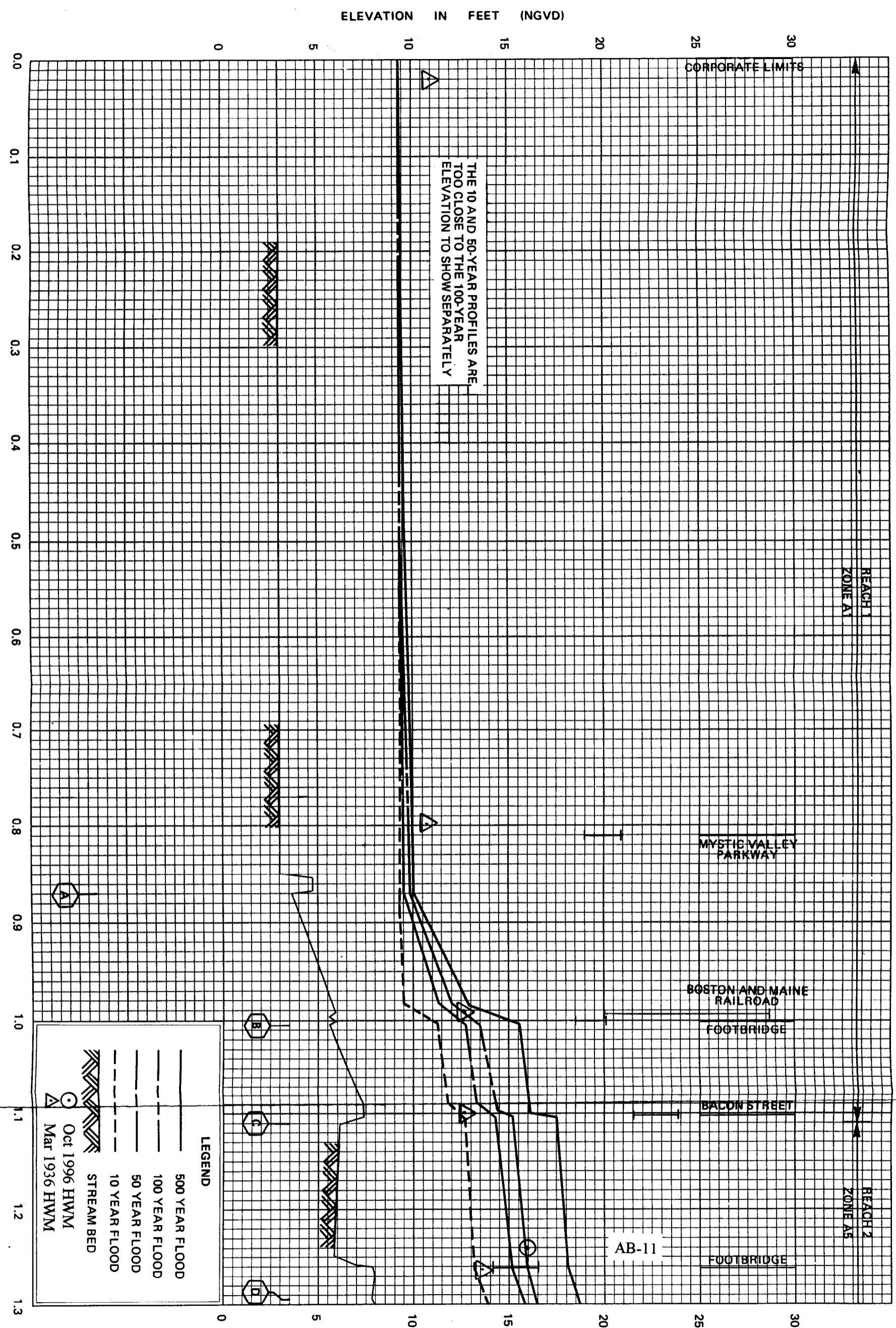


DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration

TOWN OF SALEM, NH
(ROCKINGHAM CO.)

FLOOD PROFILES

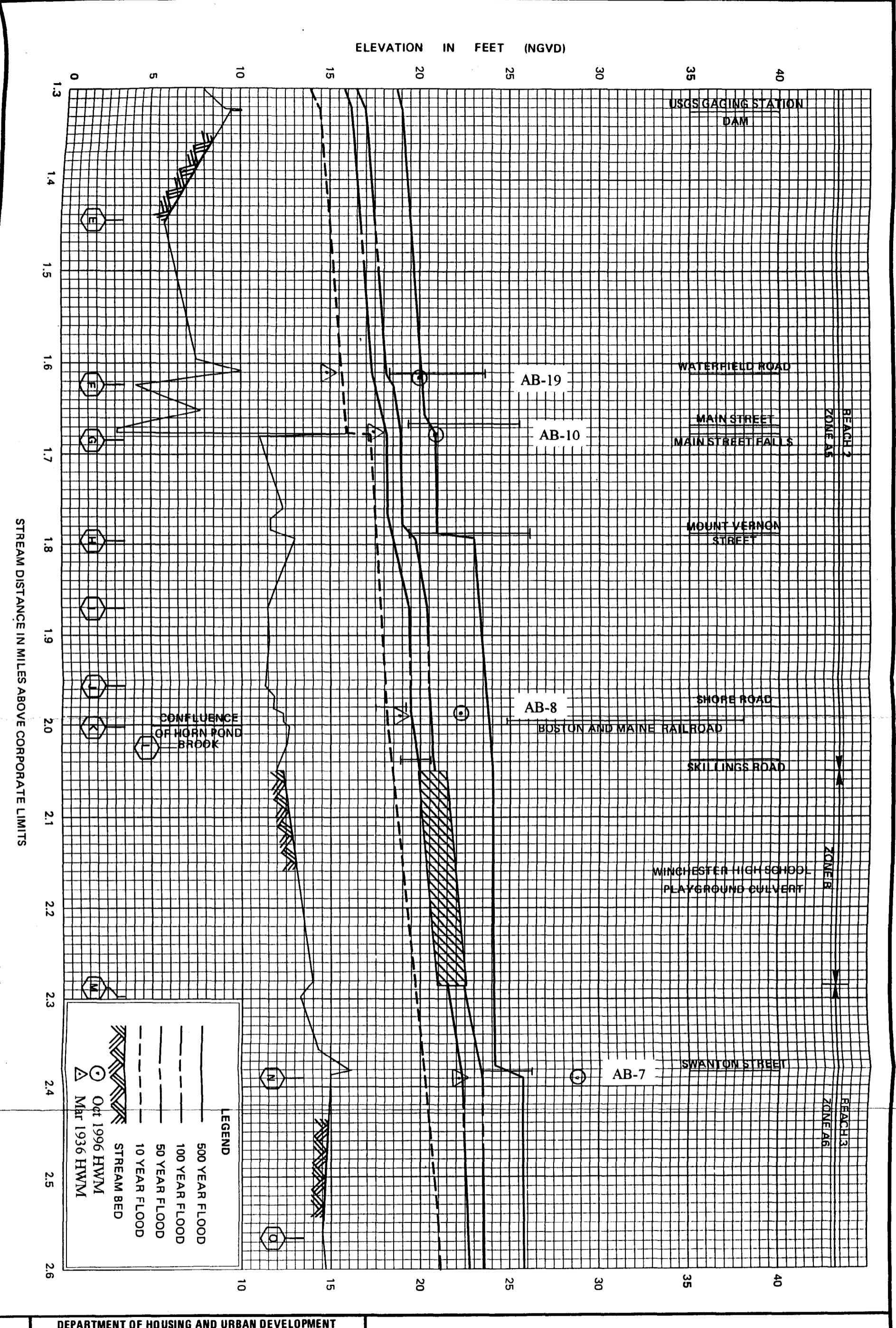
SPICKET RIVER



DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration

FLOOD PROFILES

**TOWN OF WINCHESTER, MA
(MIDDLESEX CO.)**



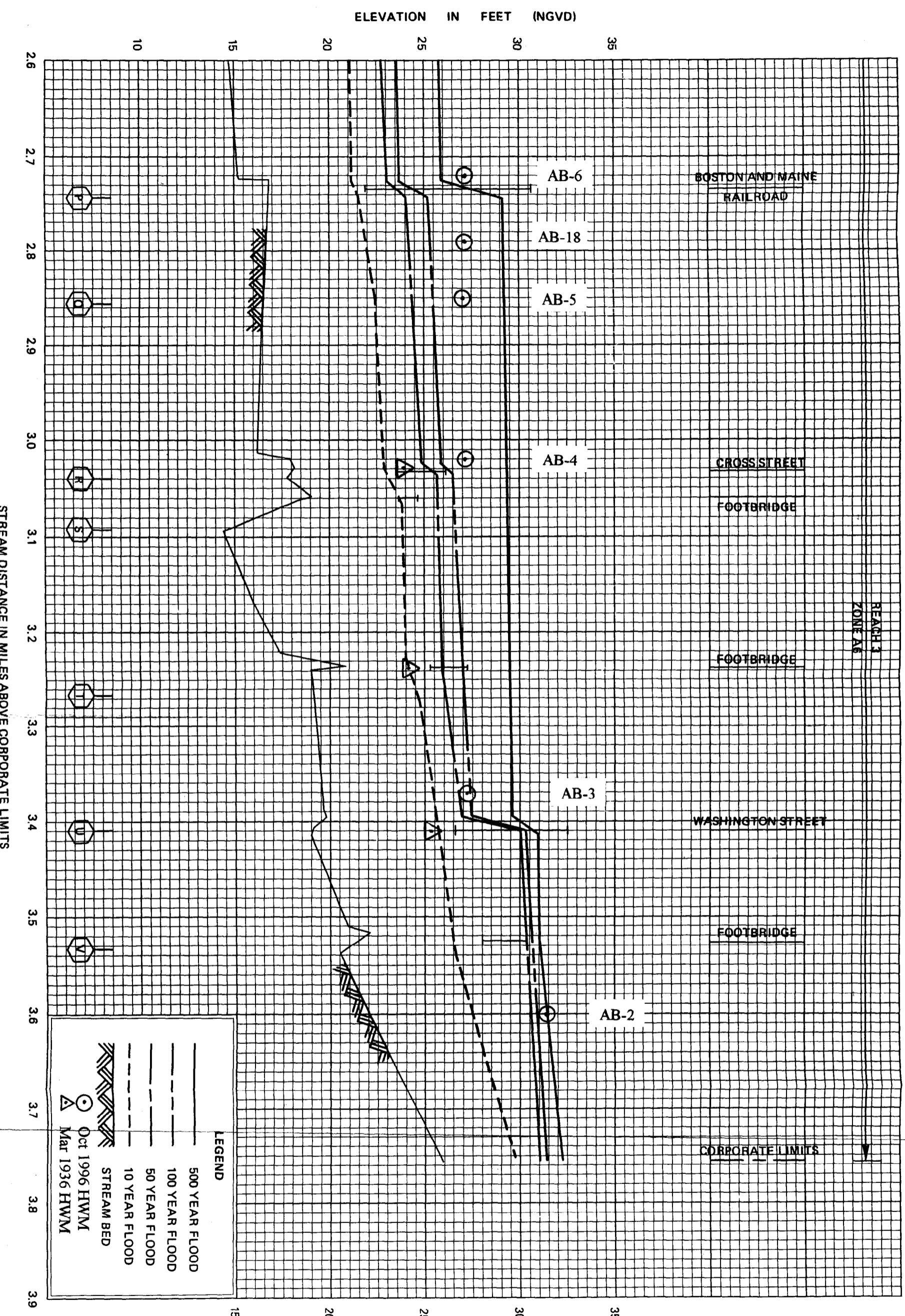
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

Federal Insurance Administration

TOWN OF WINCHESTER, MA
(MIDDLESEX CO.)

FLOOD PROFILES

ABERJONA RIVER

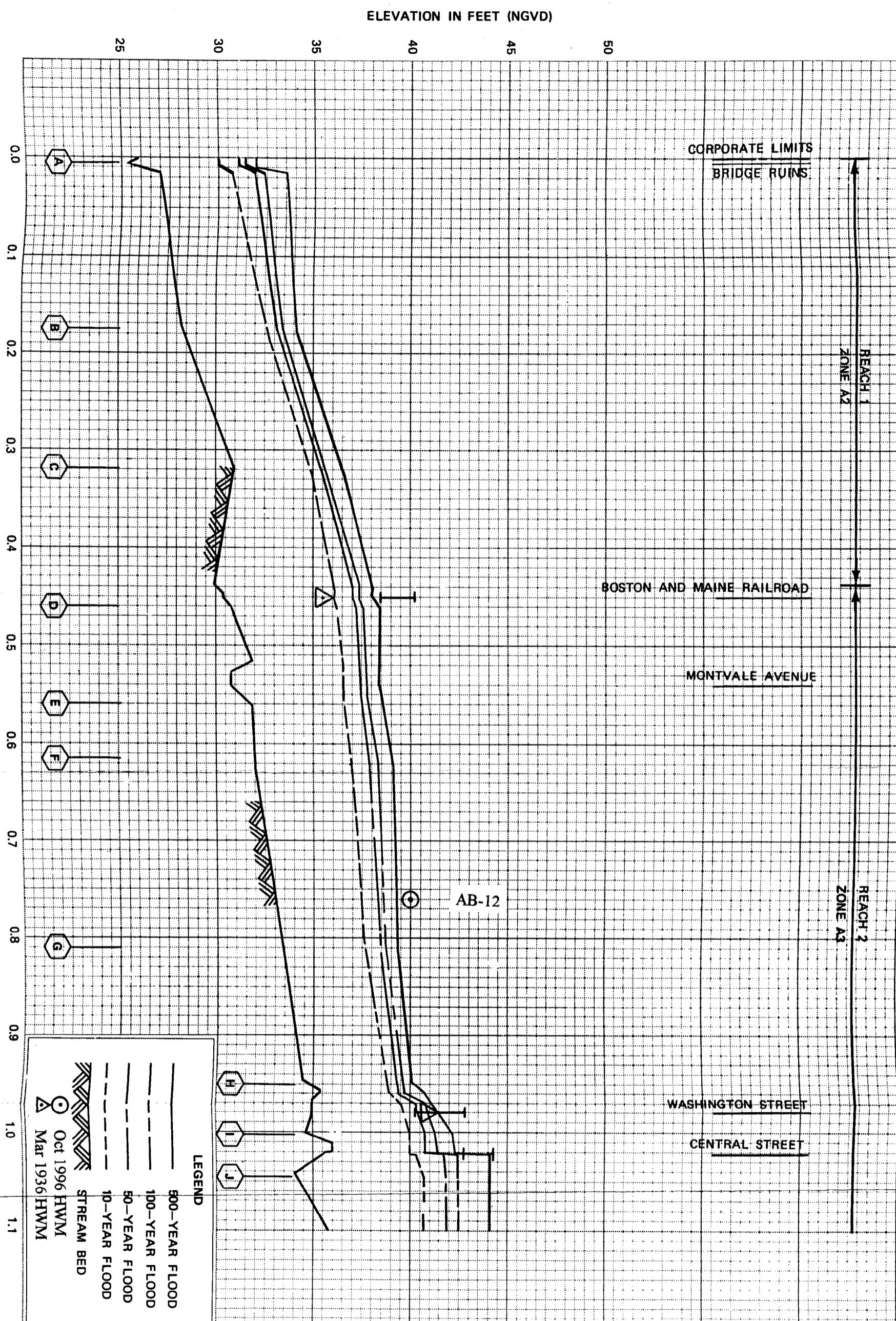


DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
Federal Insurance Administration

TOWN OF WINCHESTER, MA
(MIDDLESEX CO.)

FLOOD PROFILES

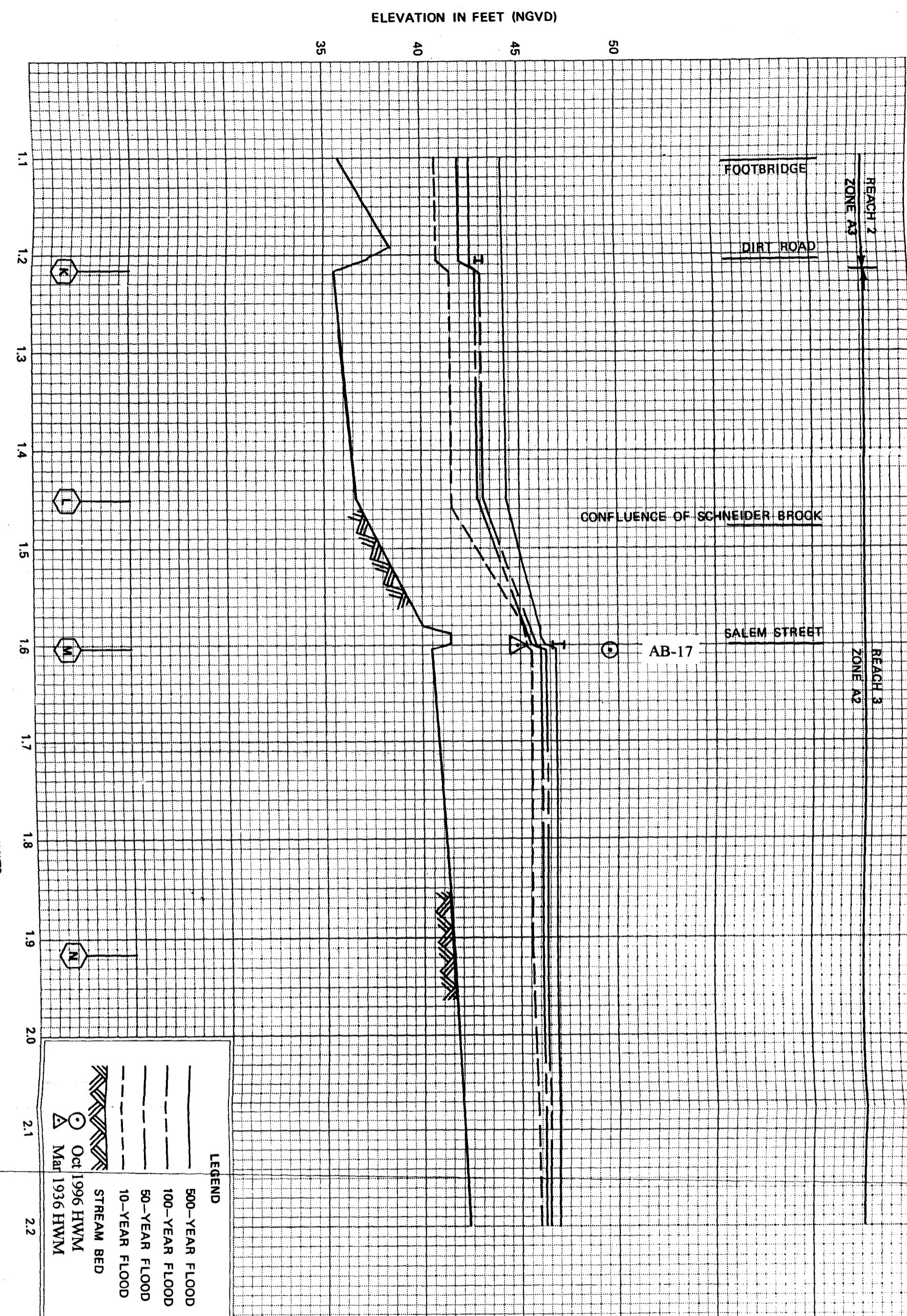
ABERJONA RIVER



FEDERAL EMERGENCY MANAGEMENT AGENCY
Federal Insurance Administration
CITY OF WOBURN, MA
(MIDDLESEX CO.)

FLOOD PROFILES

ABERJONA RIVER



FEDERAL EMERGENCY MANAGEMENT AGENCY

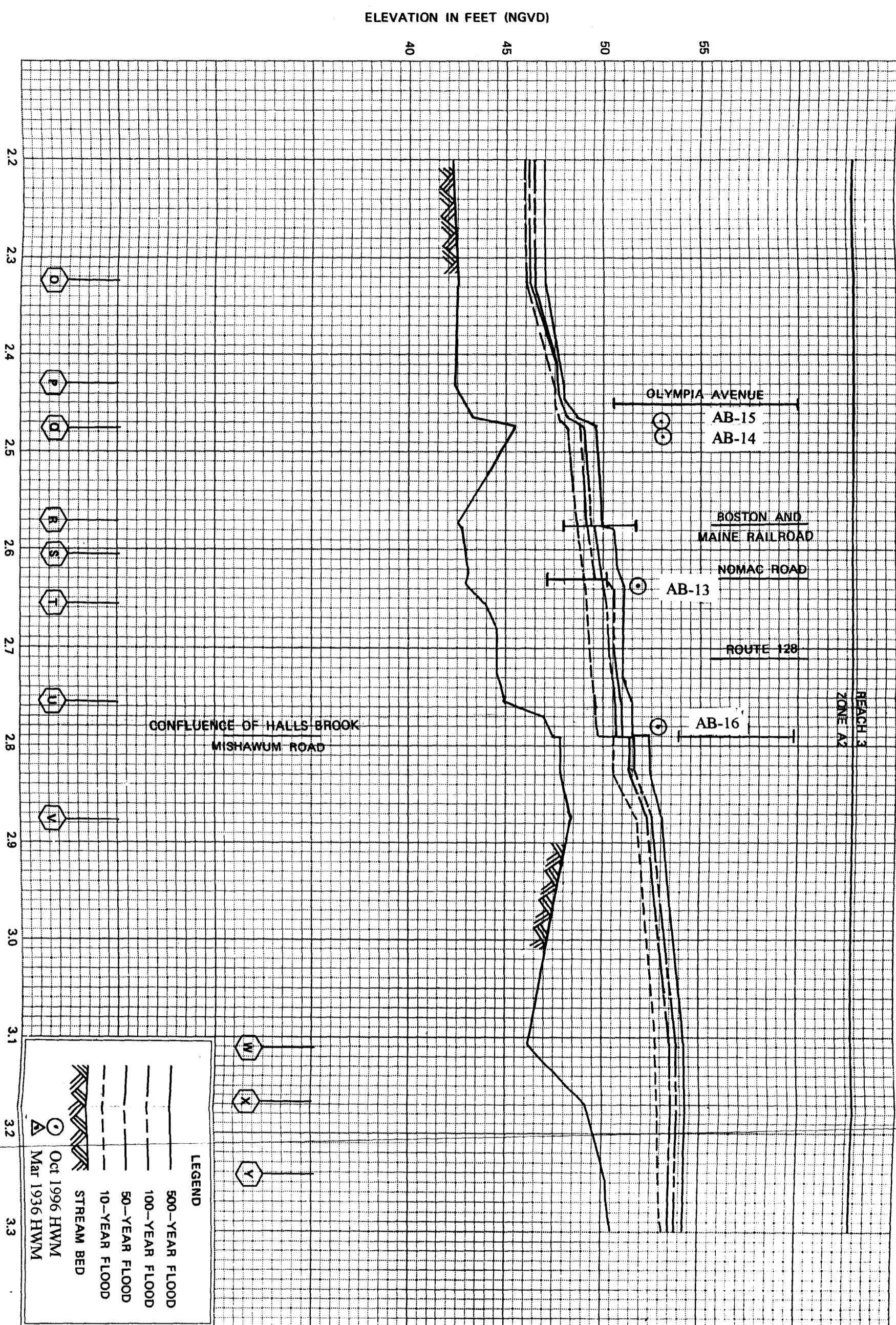
Federal Insurance Administration

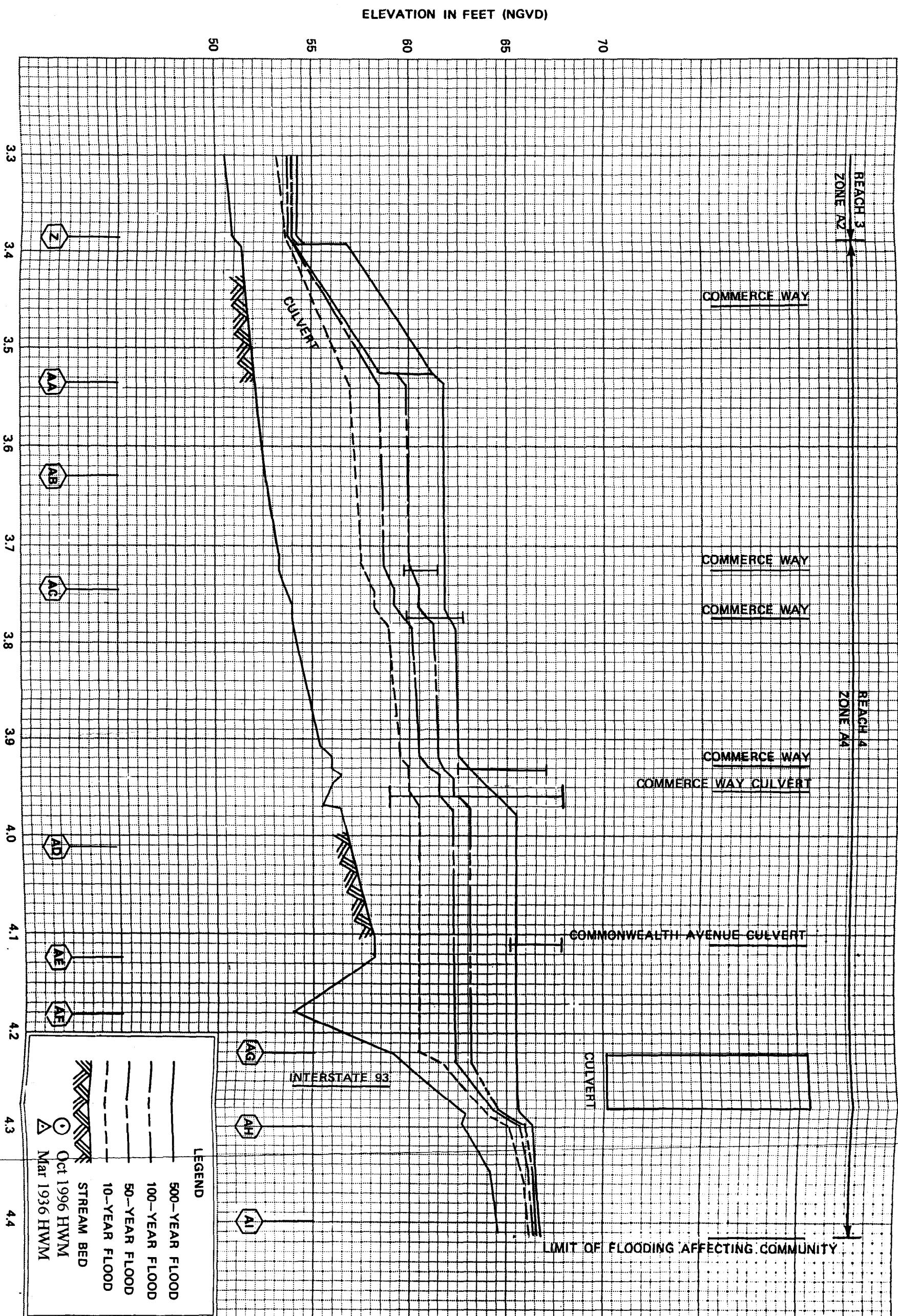
CITY OF WOBURN, MA
(MIDDLESEX CO.)

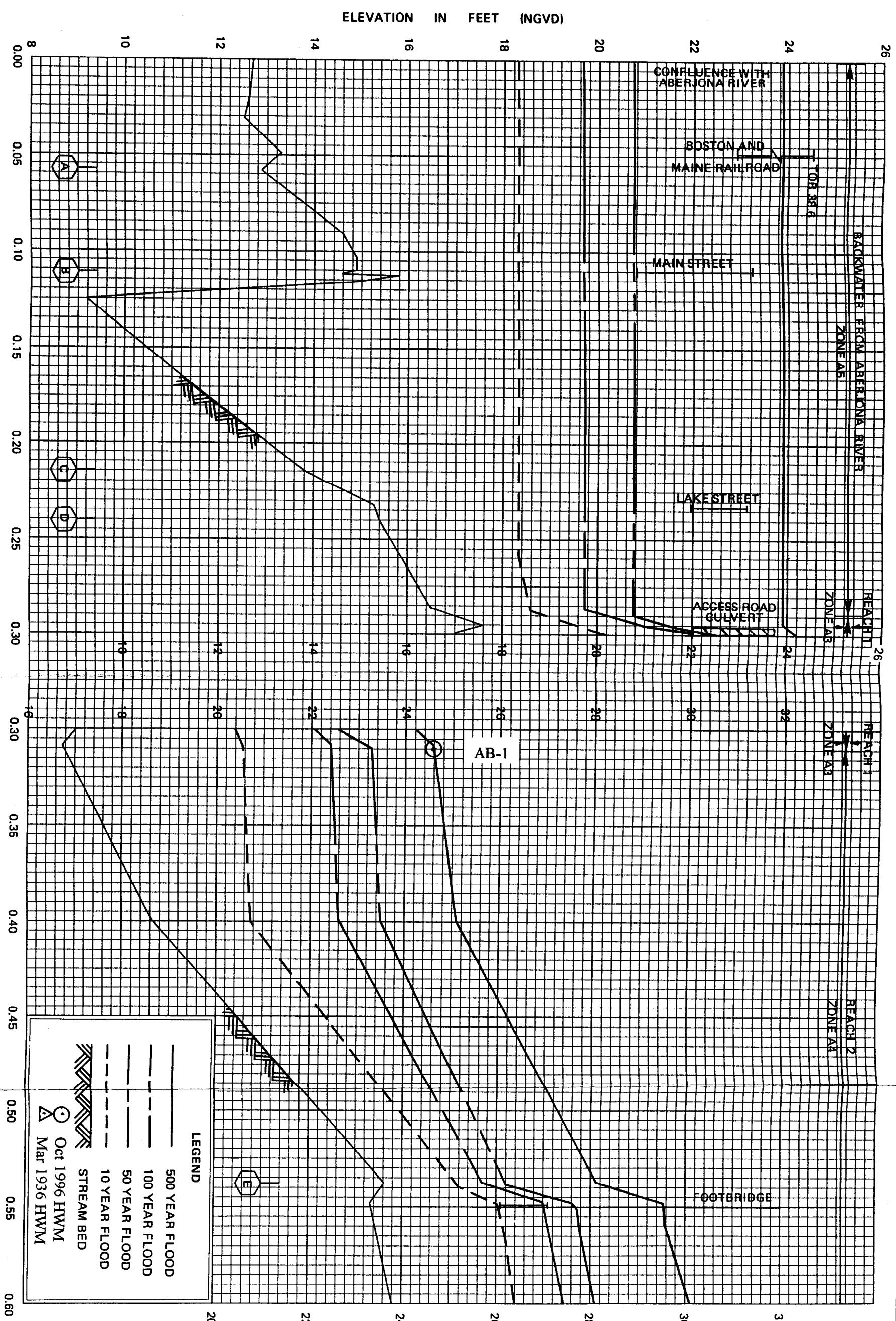
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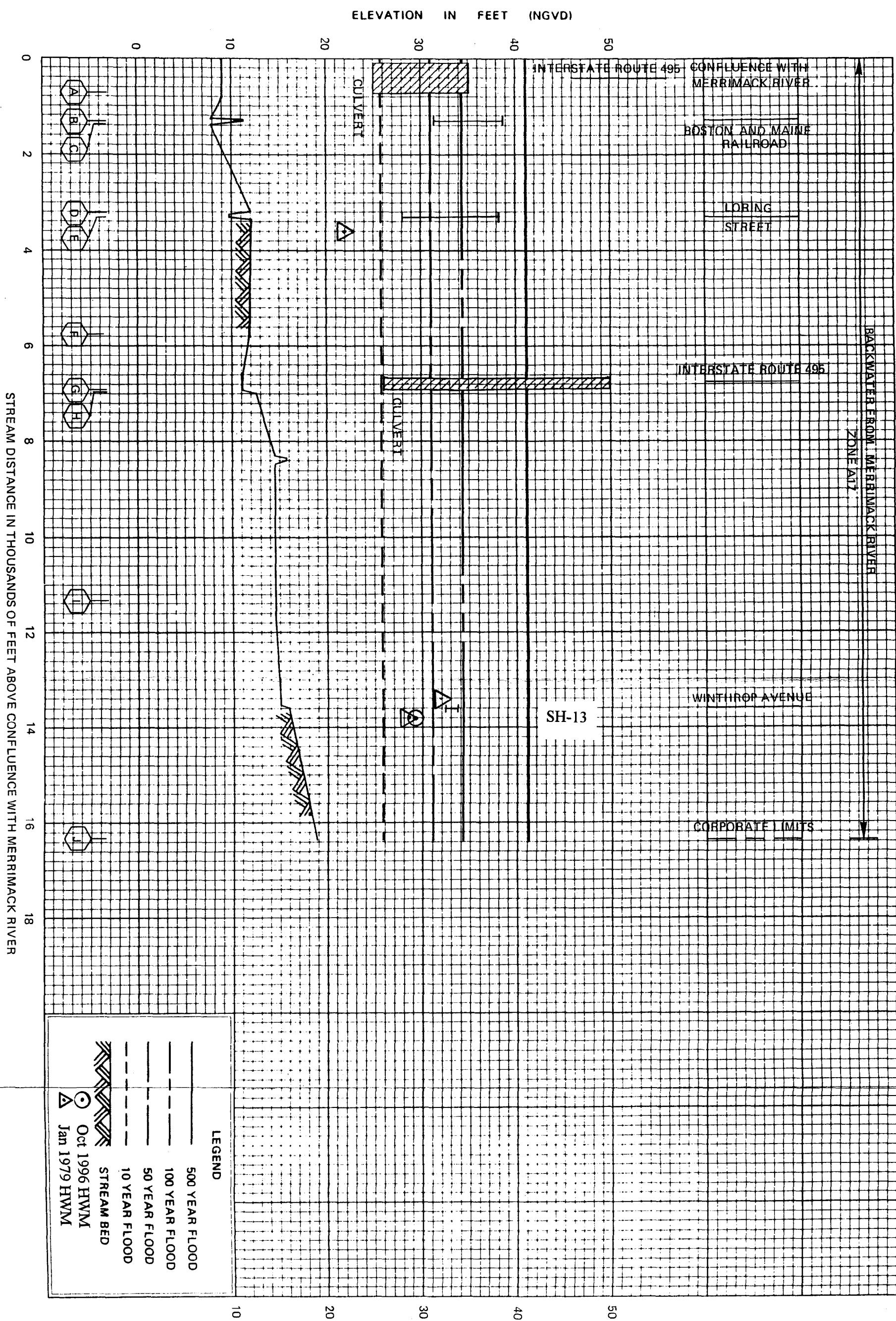
FLOOD PROFILES

ABERJONA RIVER







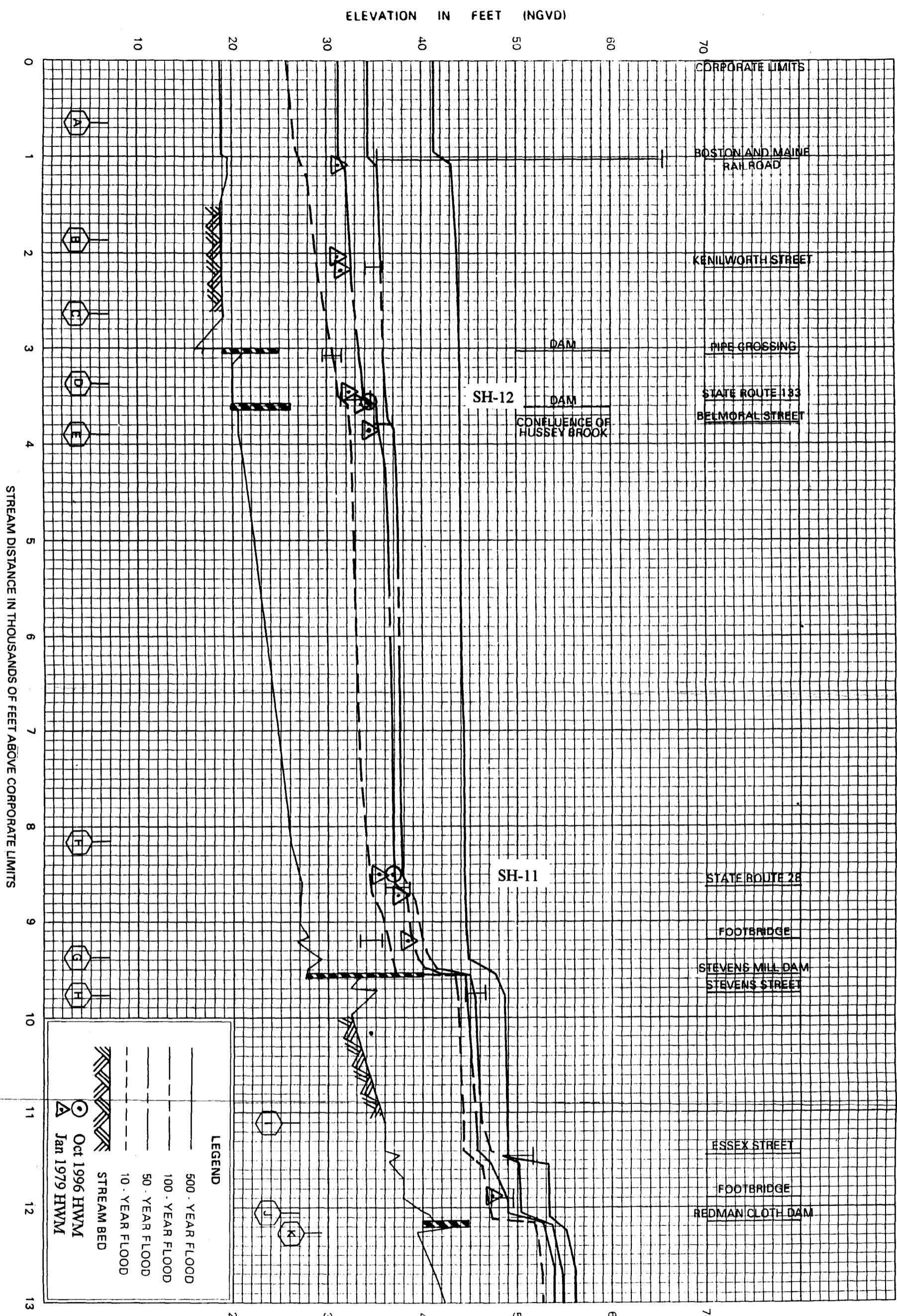


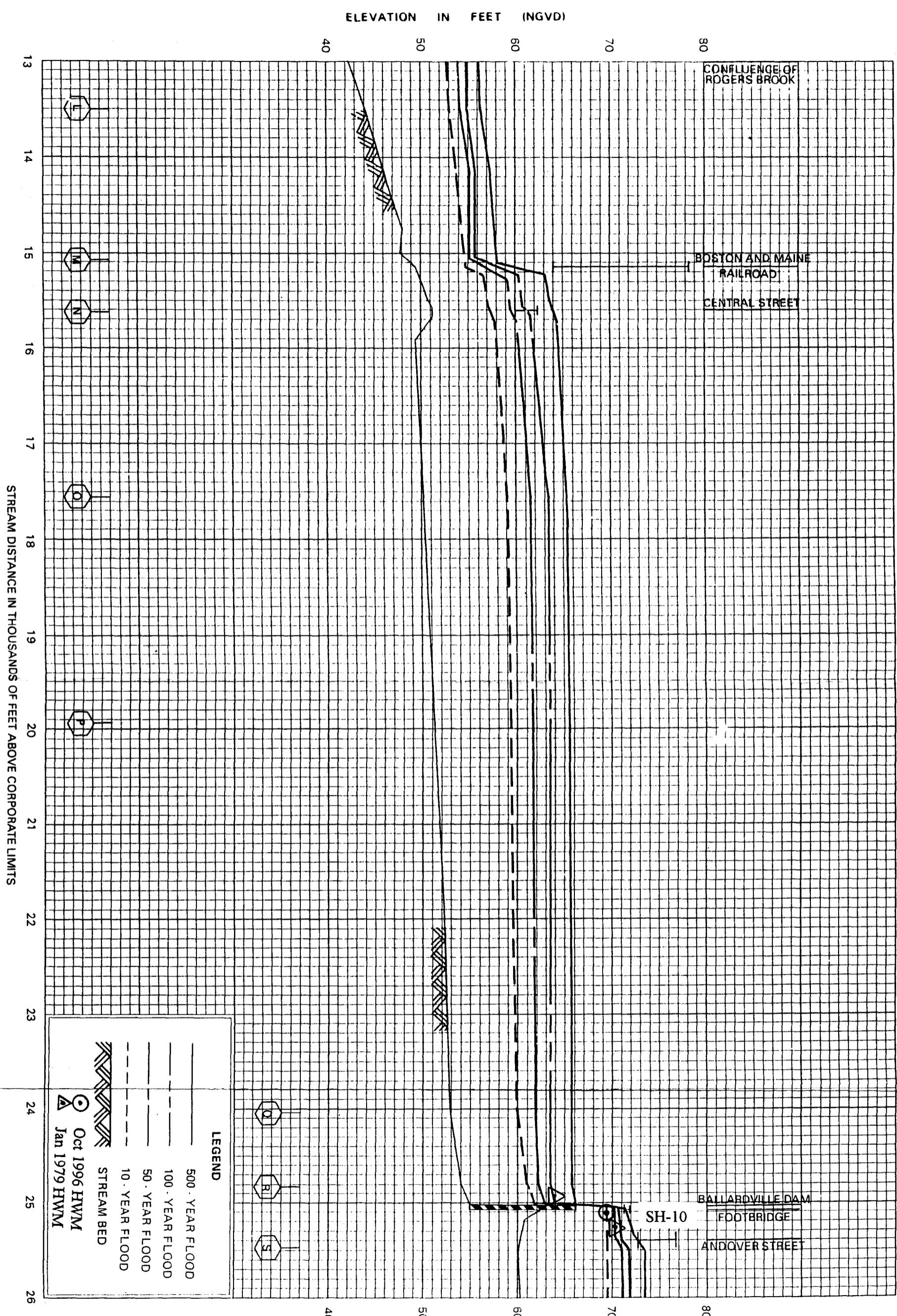
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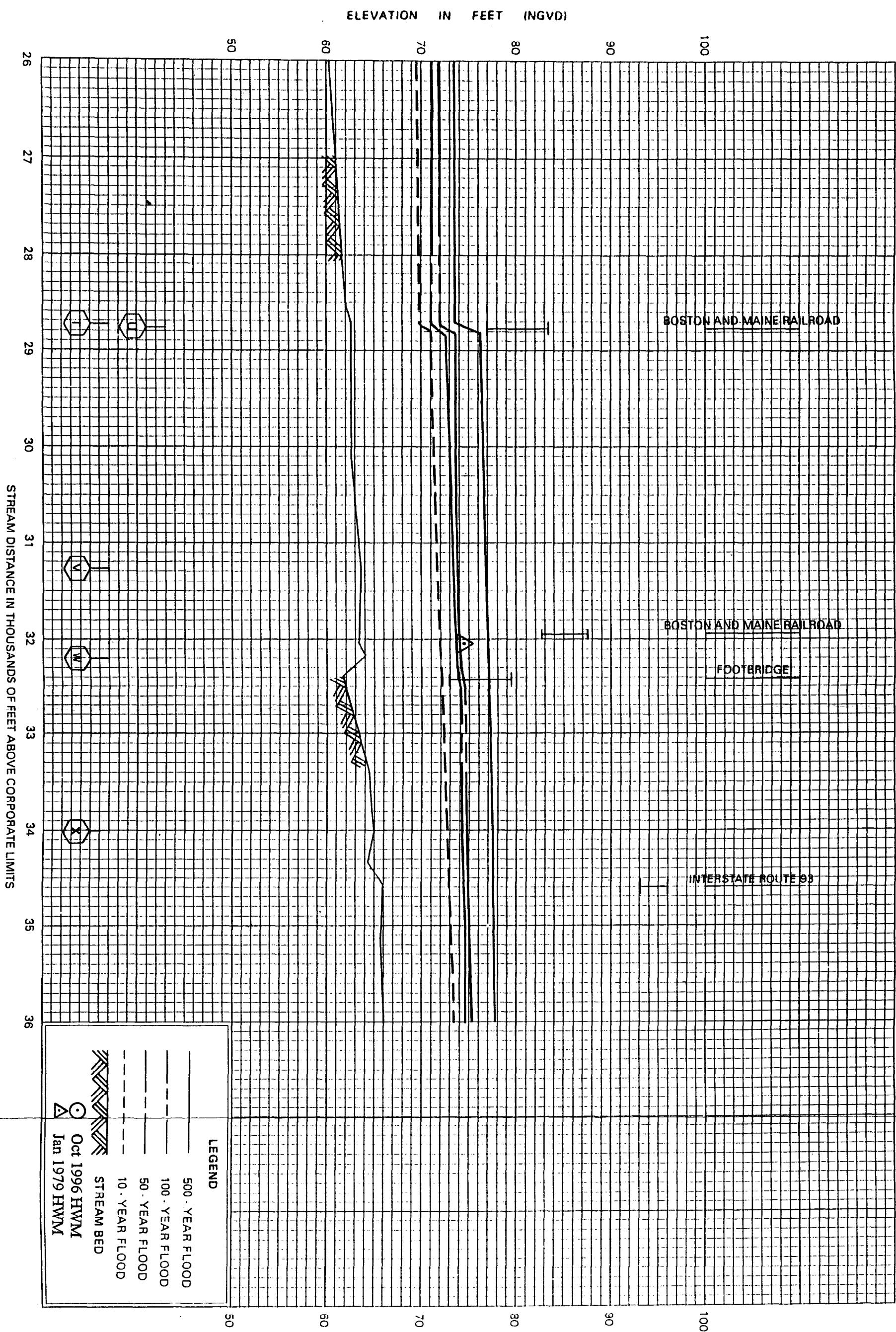
CITY OF LAWRENCE, MA
(ESSEX CO.)

FLOOD PROFILES

SHAWSHEEN RIVER





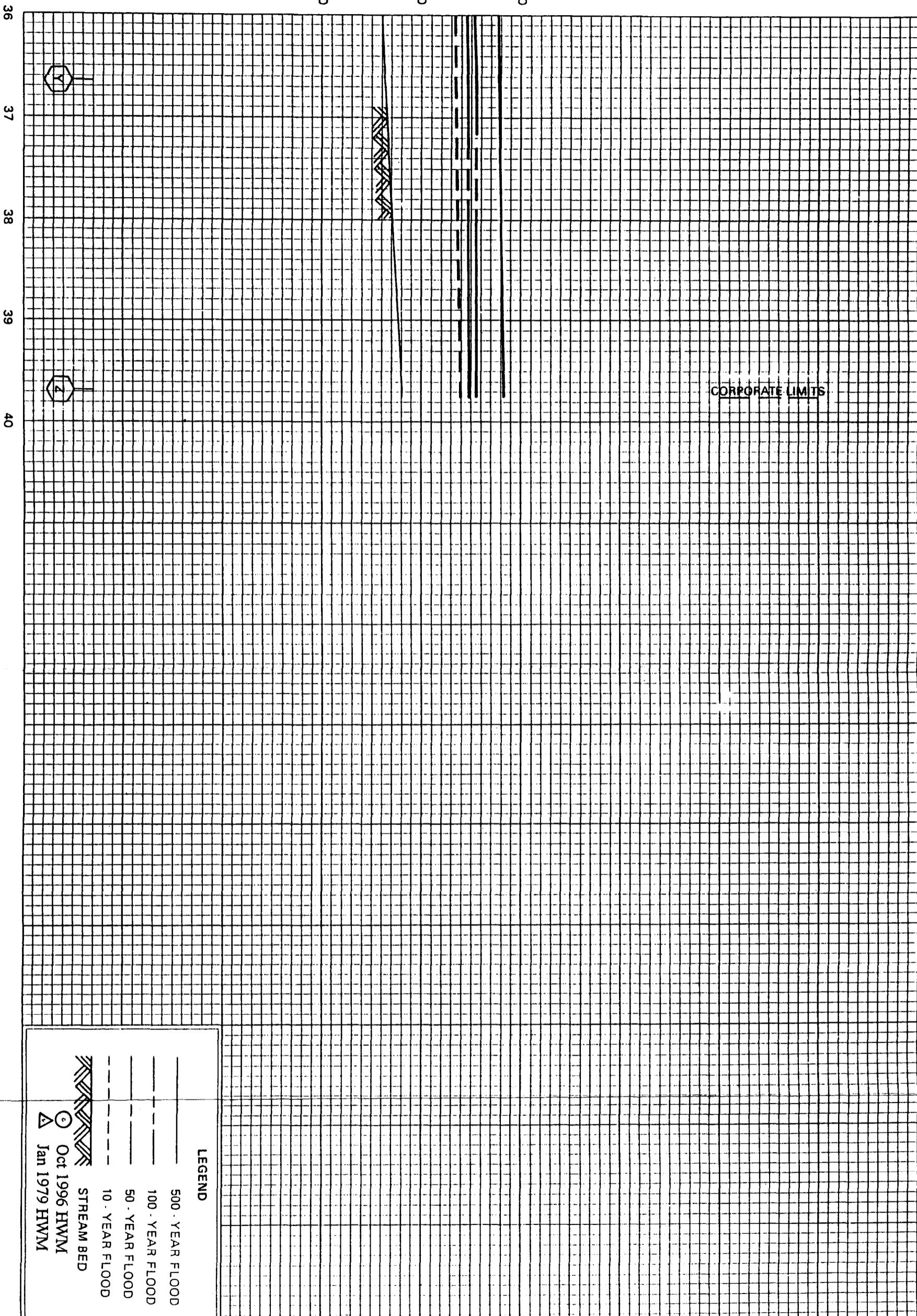


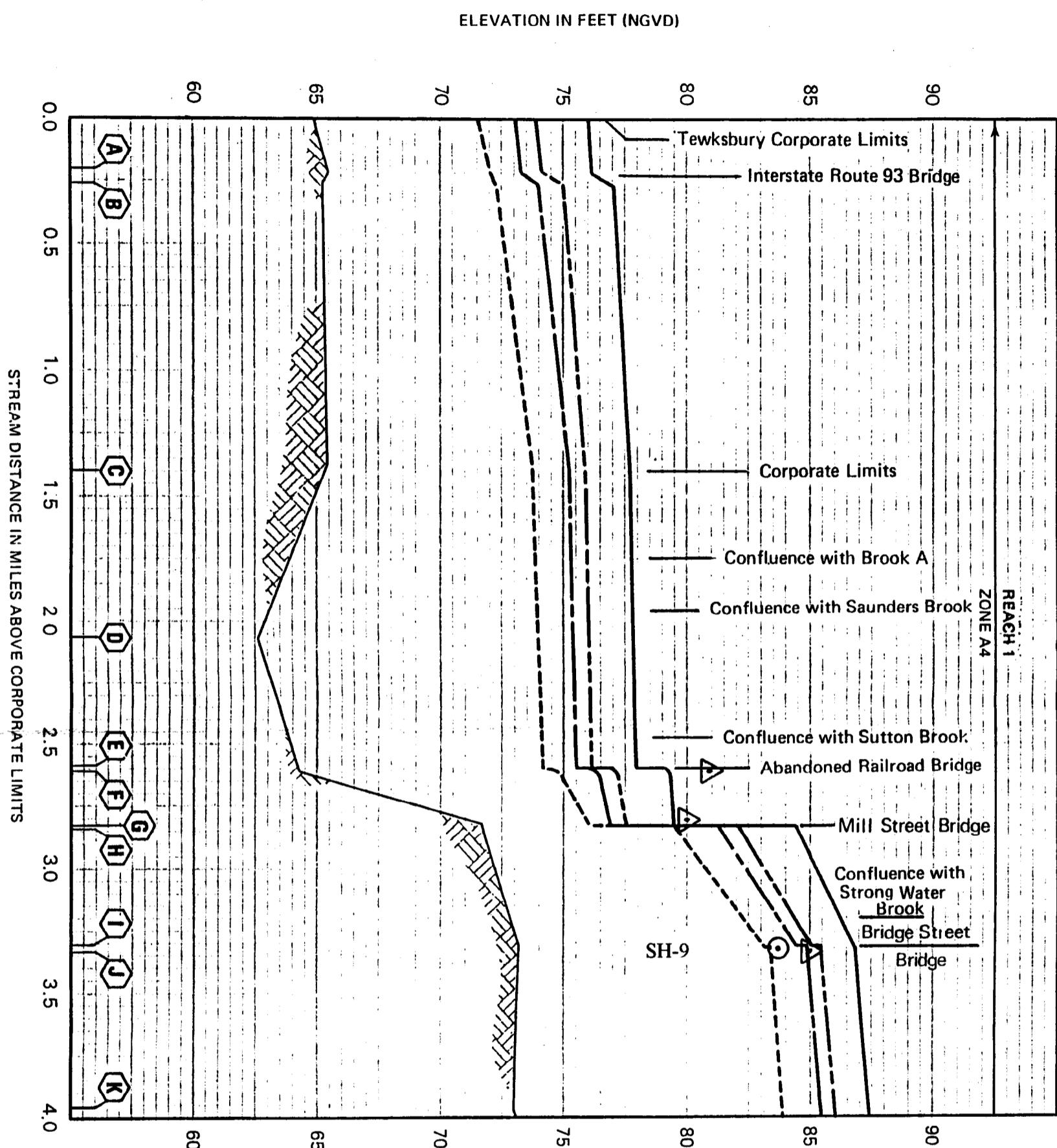
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TOWN OF ANDOVER, MA
 (ESSEX CO.)

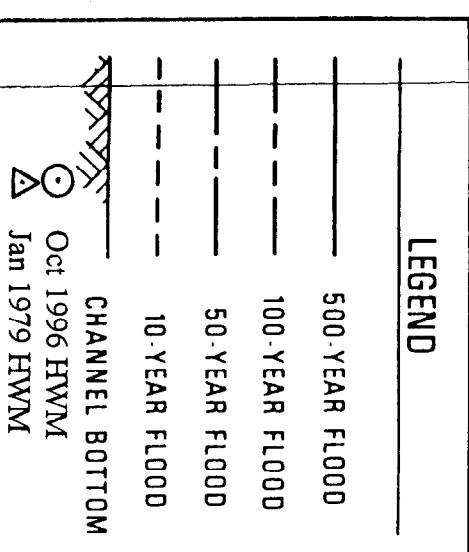
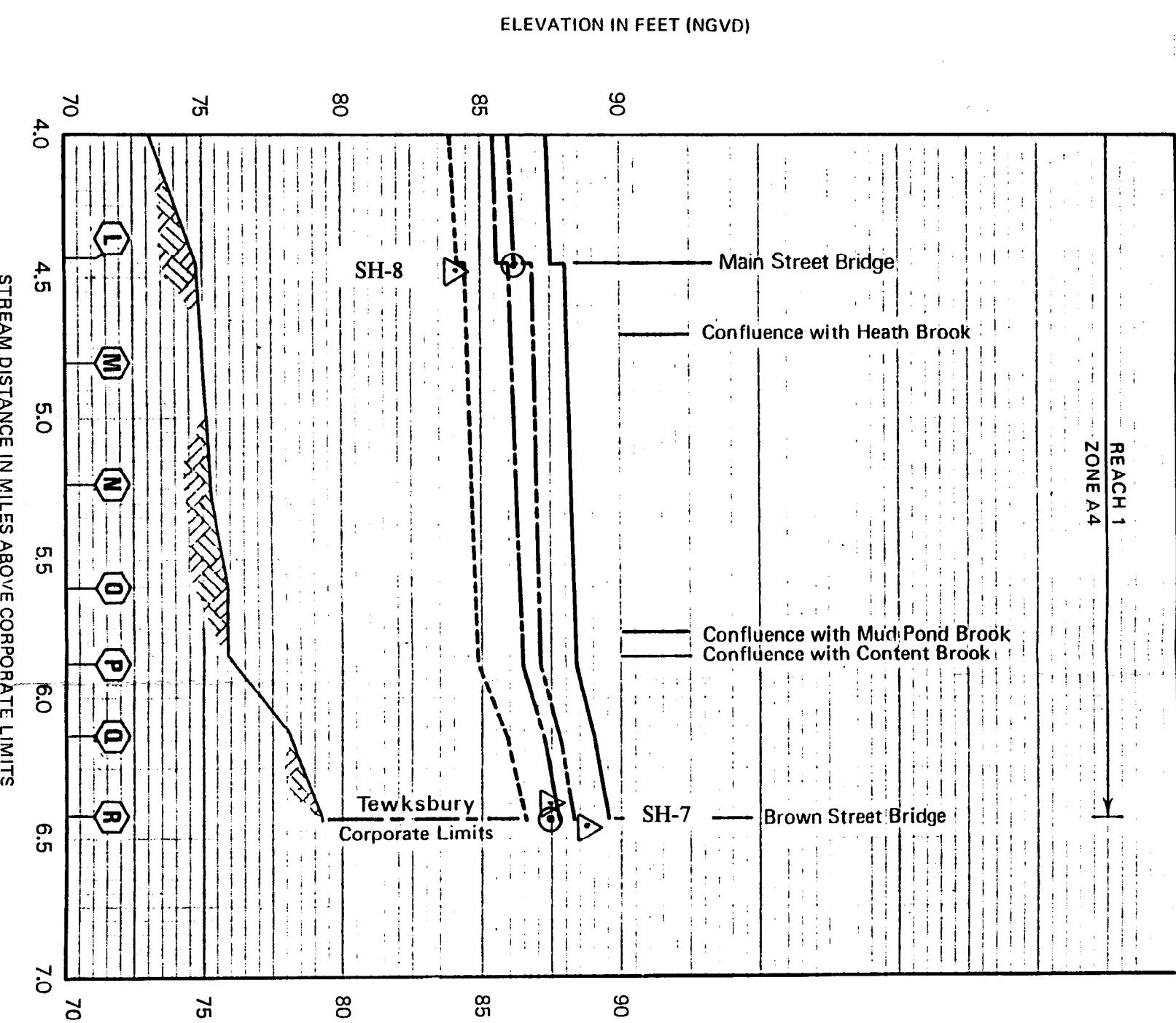
FLOOD PROFILES
SHAWSHEEN RIVER

ELEVATION IN FEET (NGVD)

60 70 80





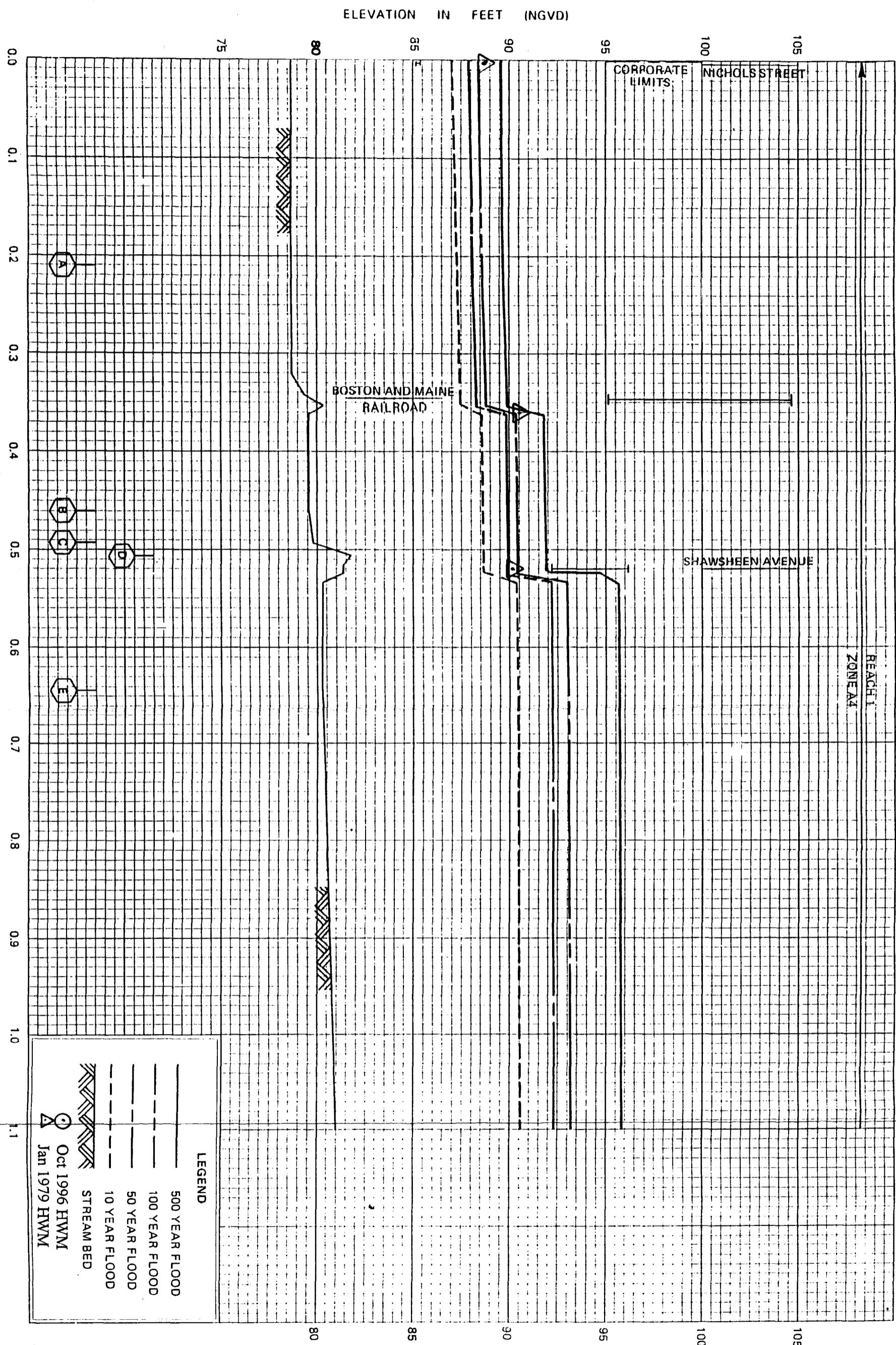


FEDERAL EMERGENCY MANAGEMENT AGENCY
Federal Insurance Administration

FLOOD PROFILES

TOWN OF TEWKSBURY, MA
(MIDDLESEX CO.)

SHAWSHEEN RIVER

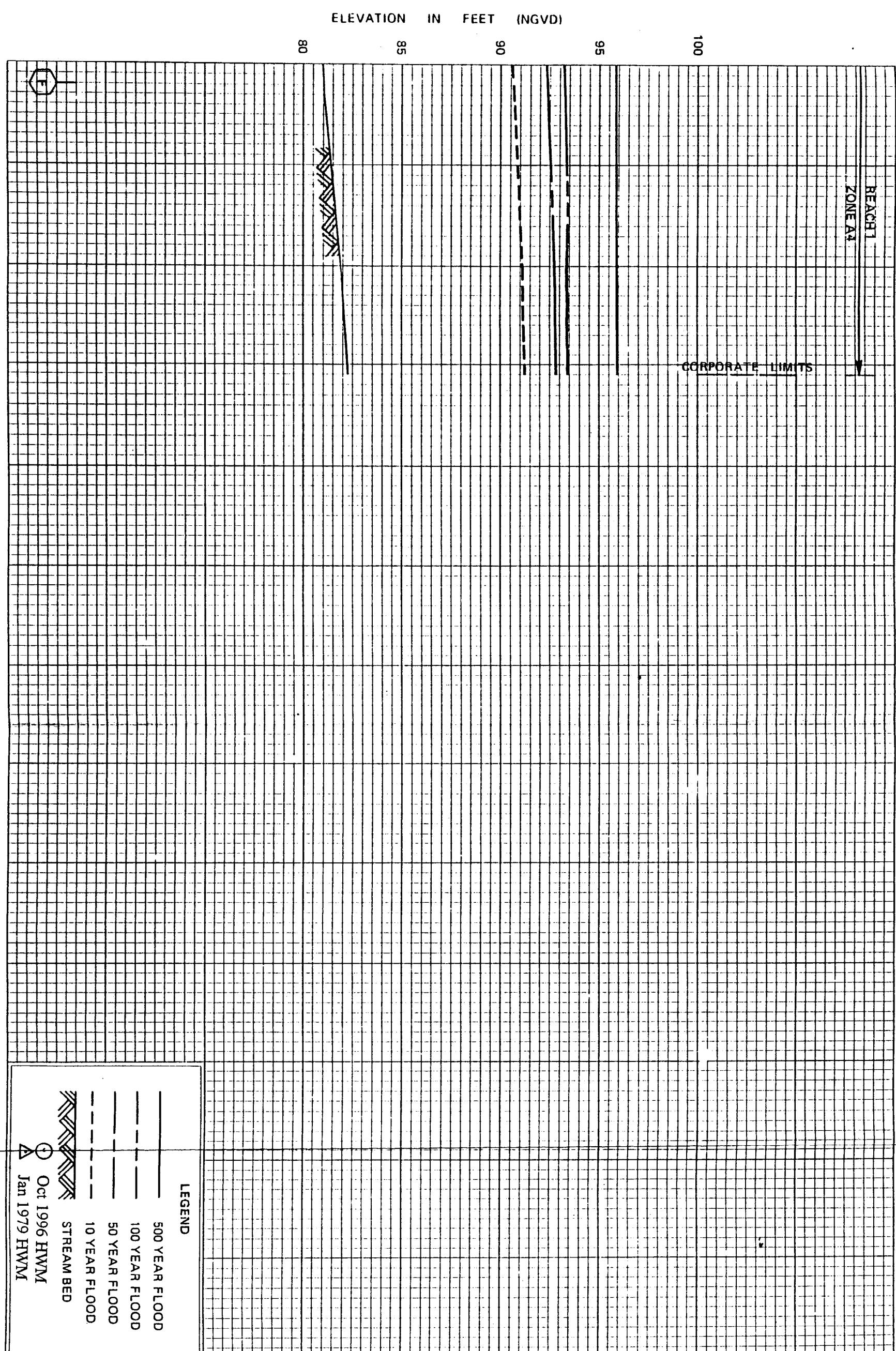


FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WILMINGTON, MA
(MIDDLESEX CO.)

FLOOD PROFILES

SHASHEEN RIVER

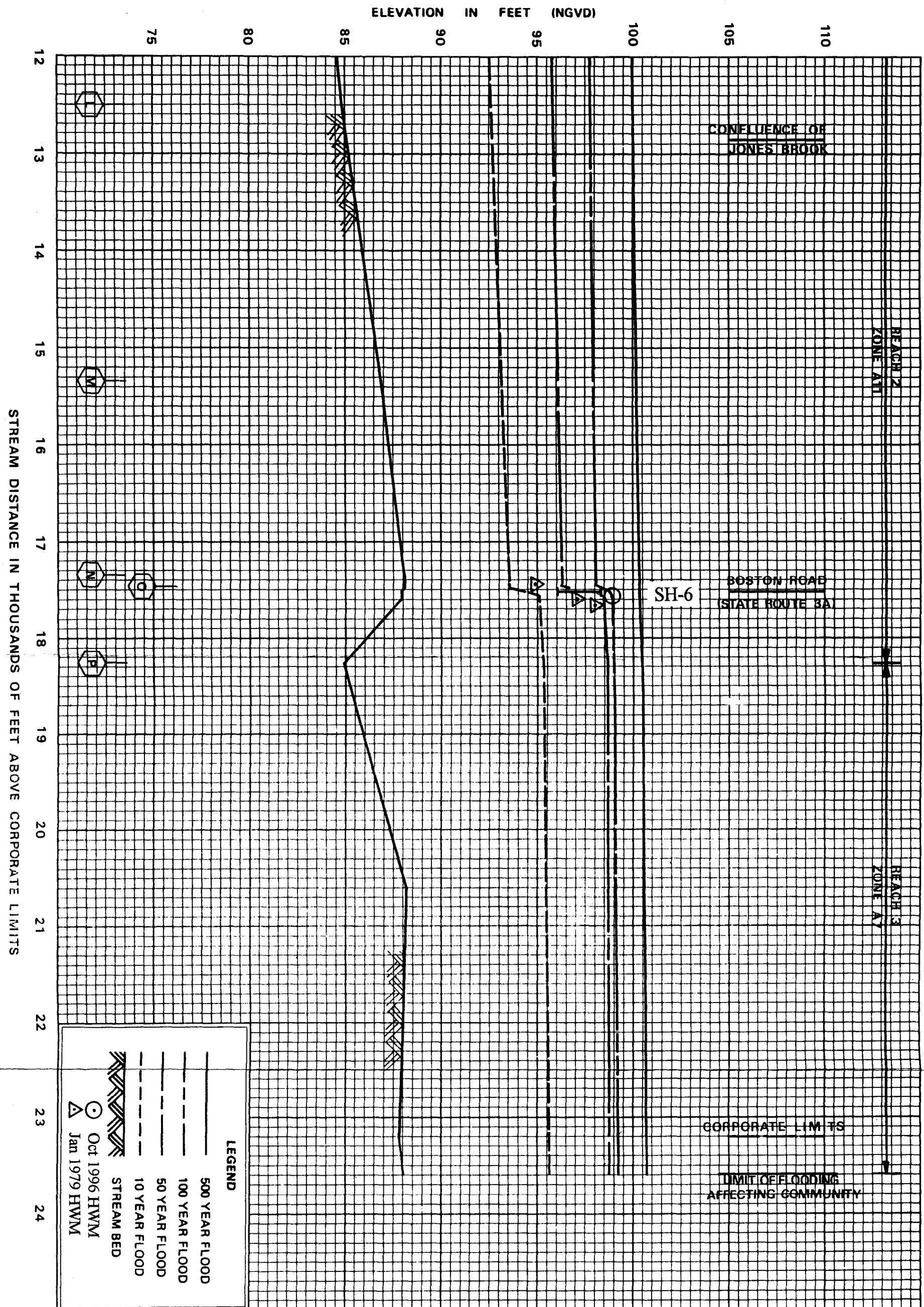


FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF WILMINGTON, MA
(MIDDLESEX CO.)

FLOOD PROFILES

SHAWSHEEN RIVER

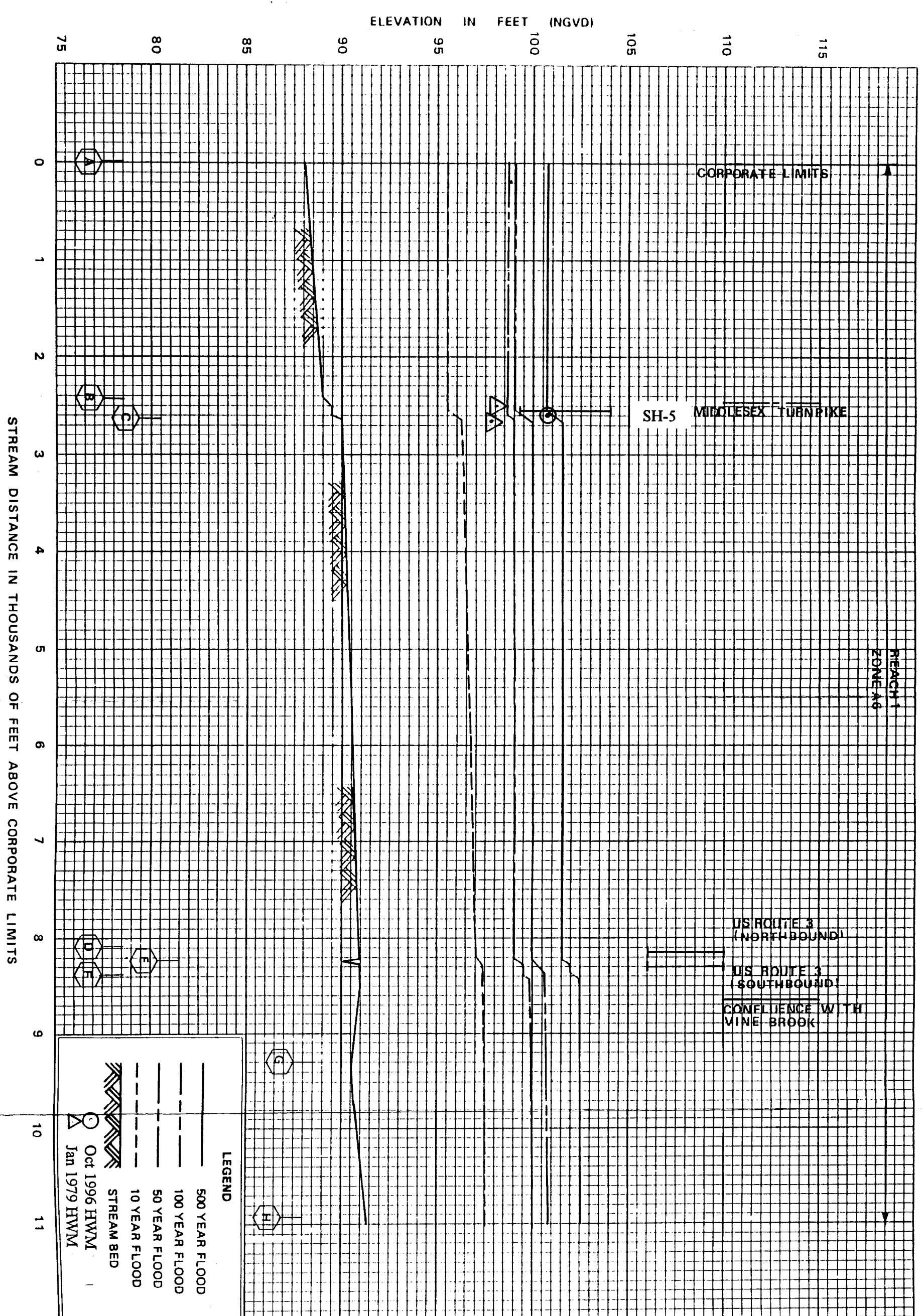


FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF BILLERICA, MA
(MIDDLESEX CO.)

FLOOD PROFILES

SHAWSHEEN RIVER

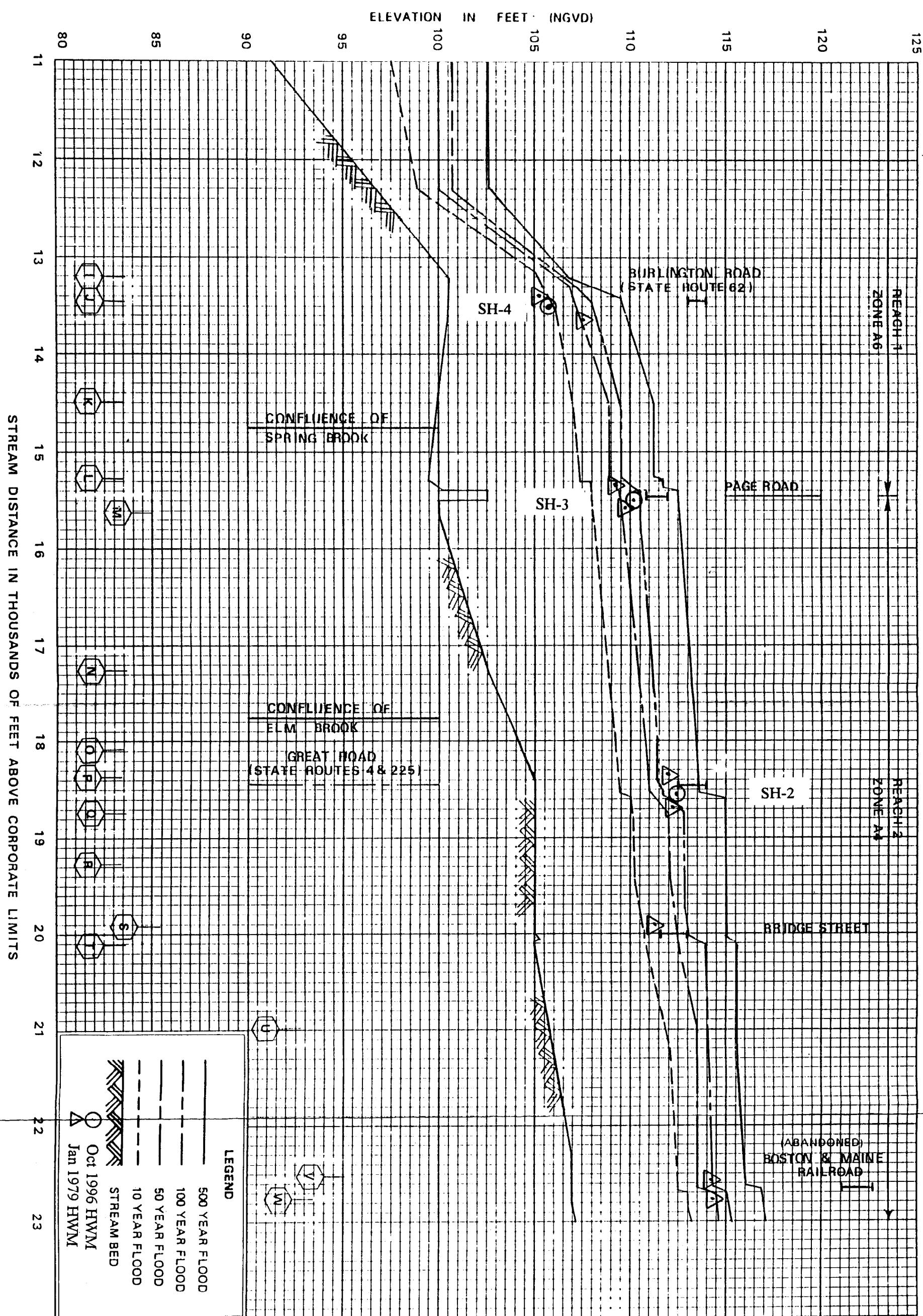


FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF BEDFORD, MA
(MIDDLESEX CO.)

FLOOD PROFILES

SHAWSHEEN RIVER

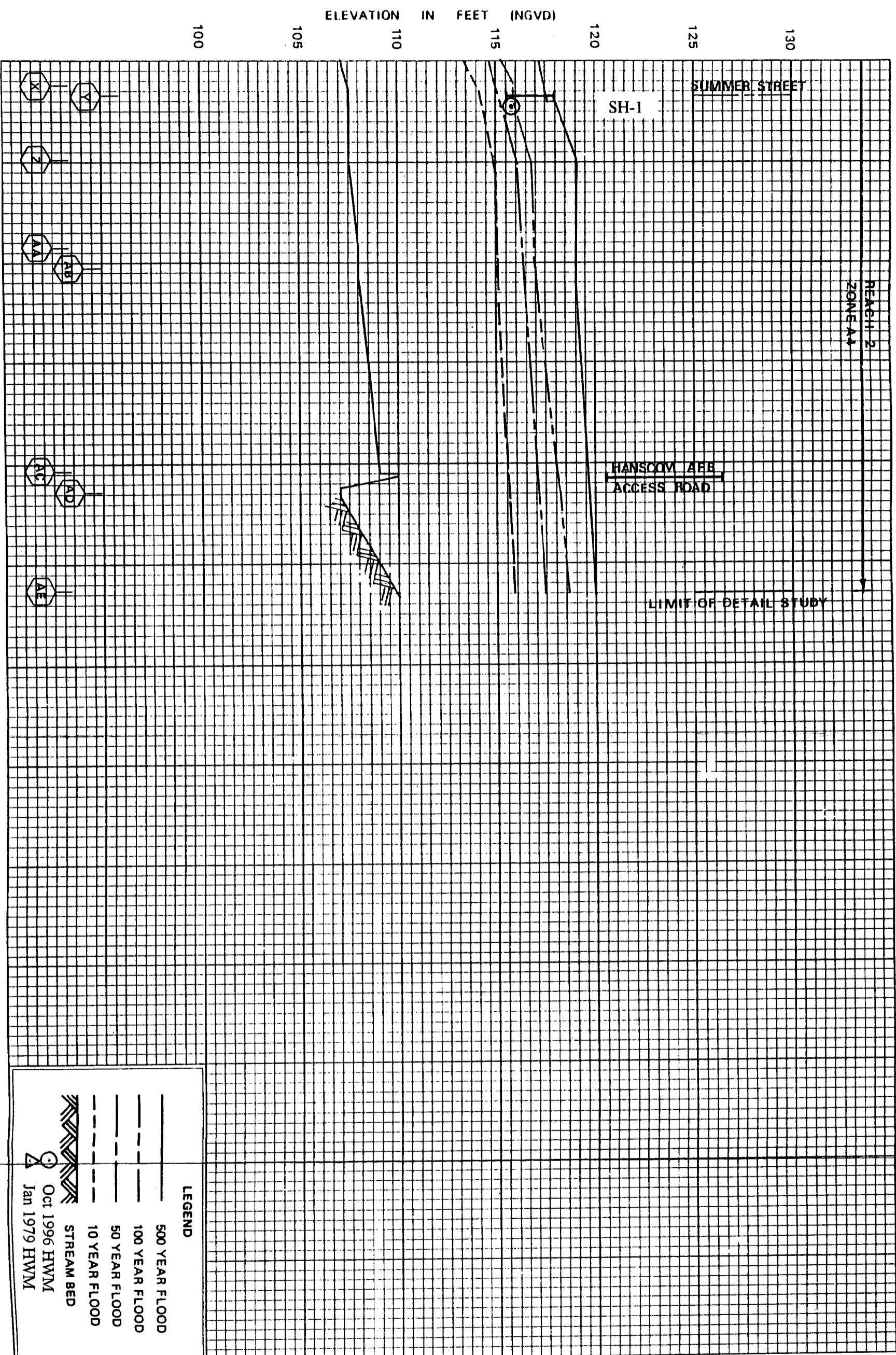


FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF BEDFORD, MA
(MIDDLESEX CO.)

FLOOD PROFILES

SHAWSHEEN RIVER

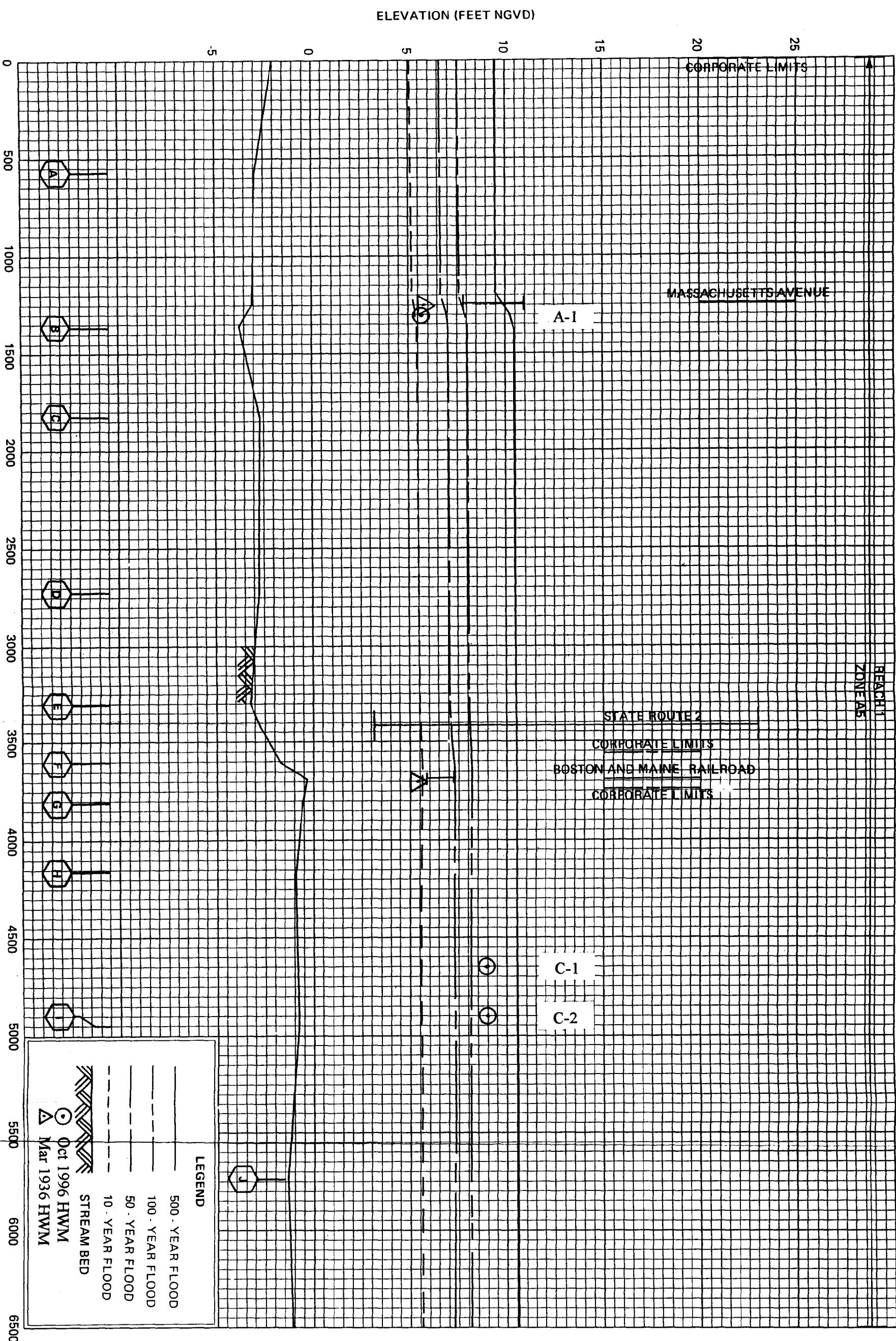


FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF BEDFORD, MA
(MIDDLESEX CO.)

FLOOD PROFILES

SHAWSHEEN RIVER



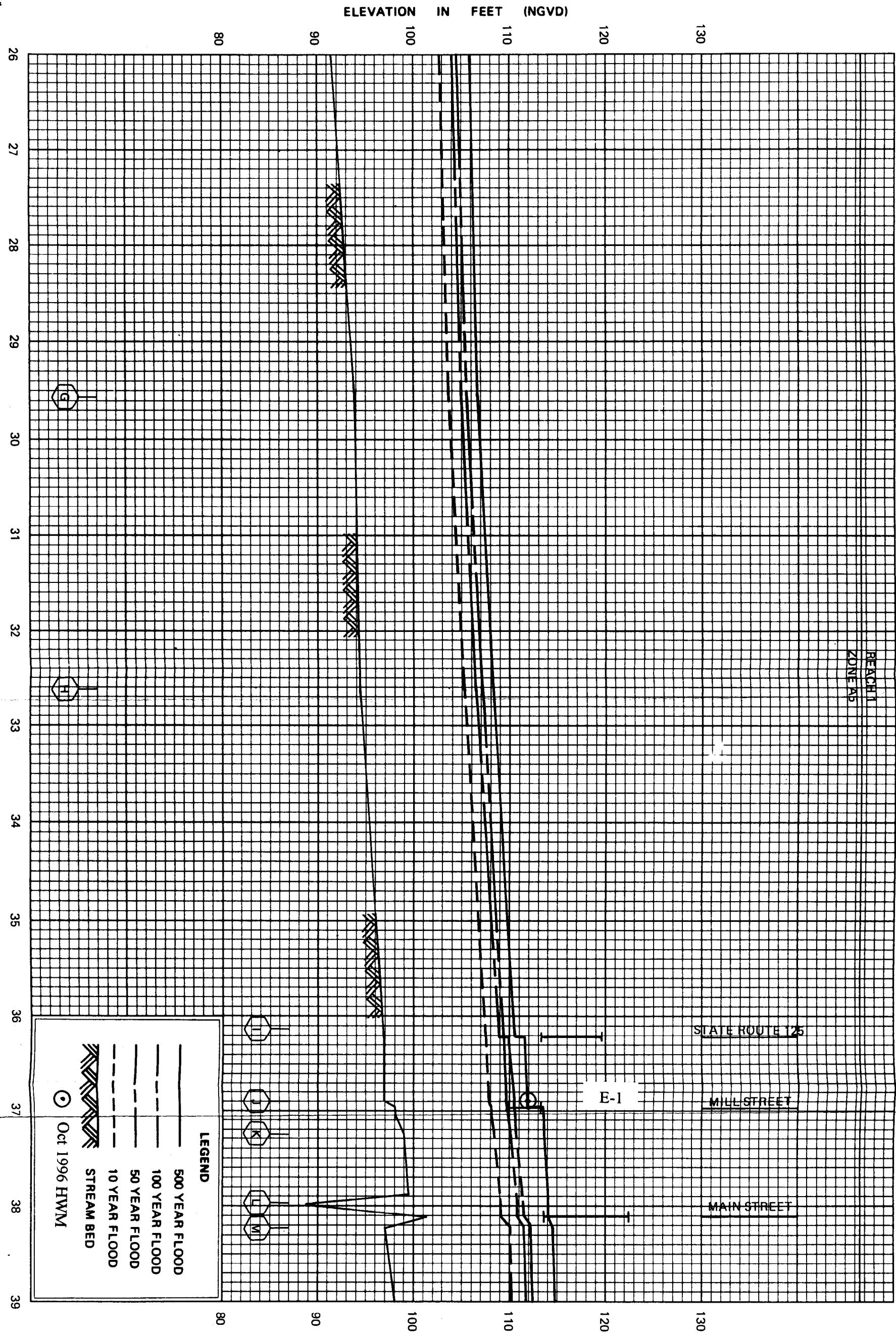
FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF CAMBRIDGE, MA
(MIDDLESEX CO.)

01P

FLOOD PROFILES

ALEWIFE BROOK



FEDERAL EMERGENCY MANAGEMENT AGENCY

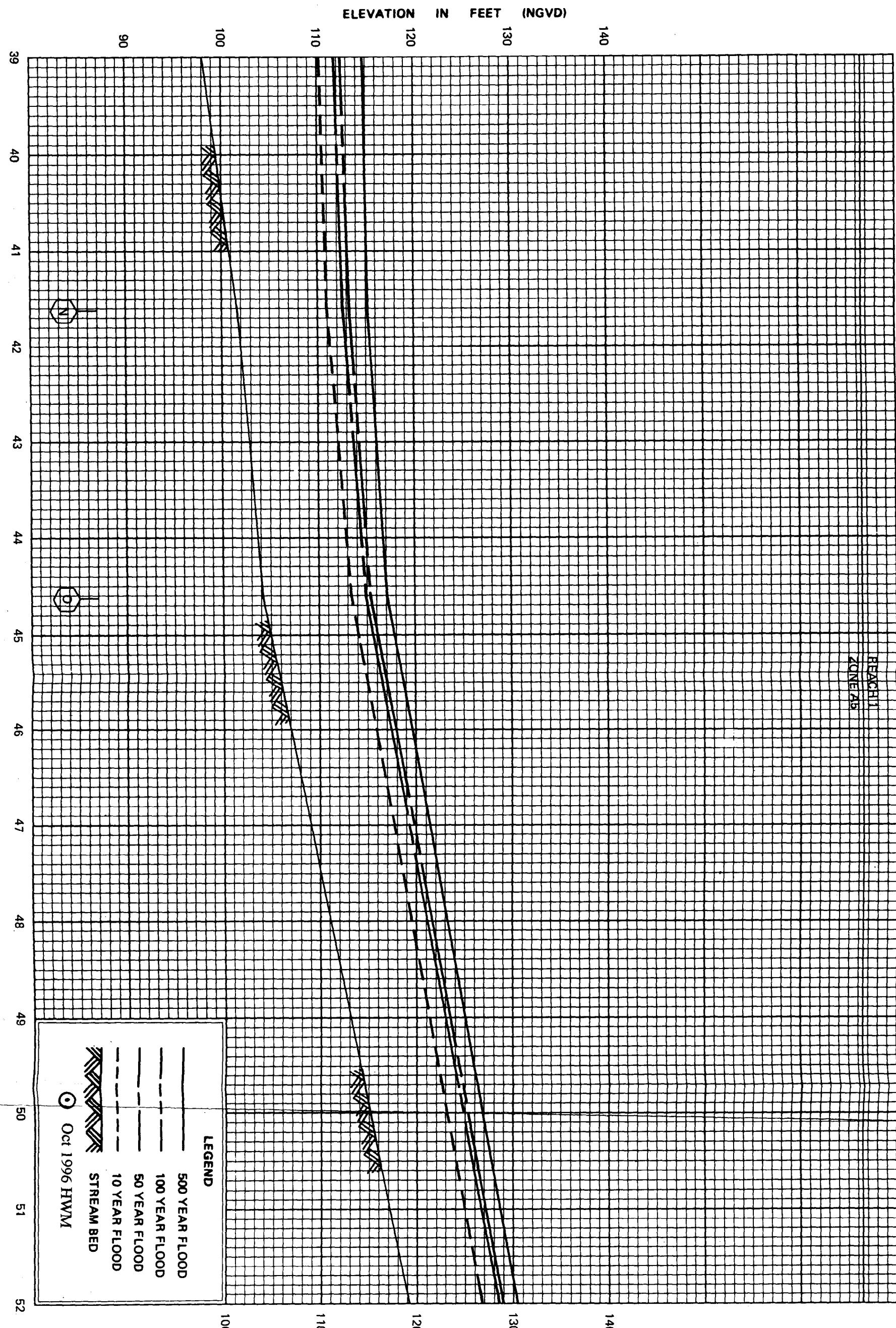
FLOOD PROFILES

TOWN OF EPPING, NH

(ROCKINGHAM CO.)

LAMPREY RIVER

STREAM DISTANCE IN THOUSANDS OF FEET ABOVE CORPORATE LIMITS

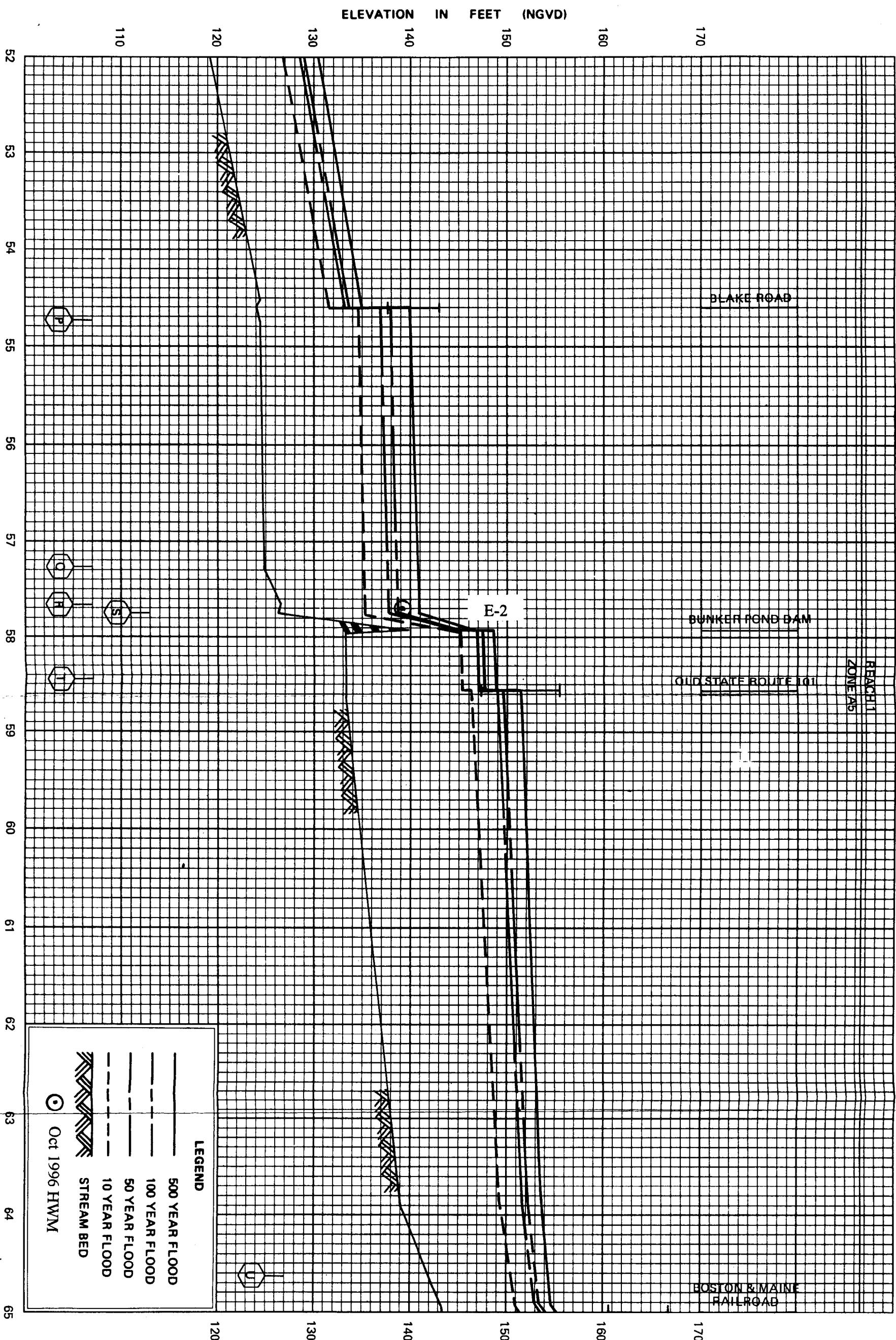


FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF EPPING, NH
(ROCKINGHAM CO.)

FLOOD PROFILES

LAMPREY RIVER

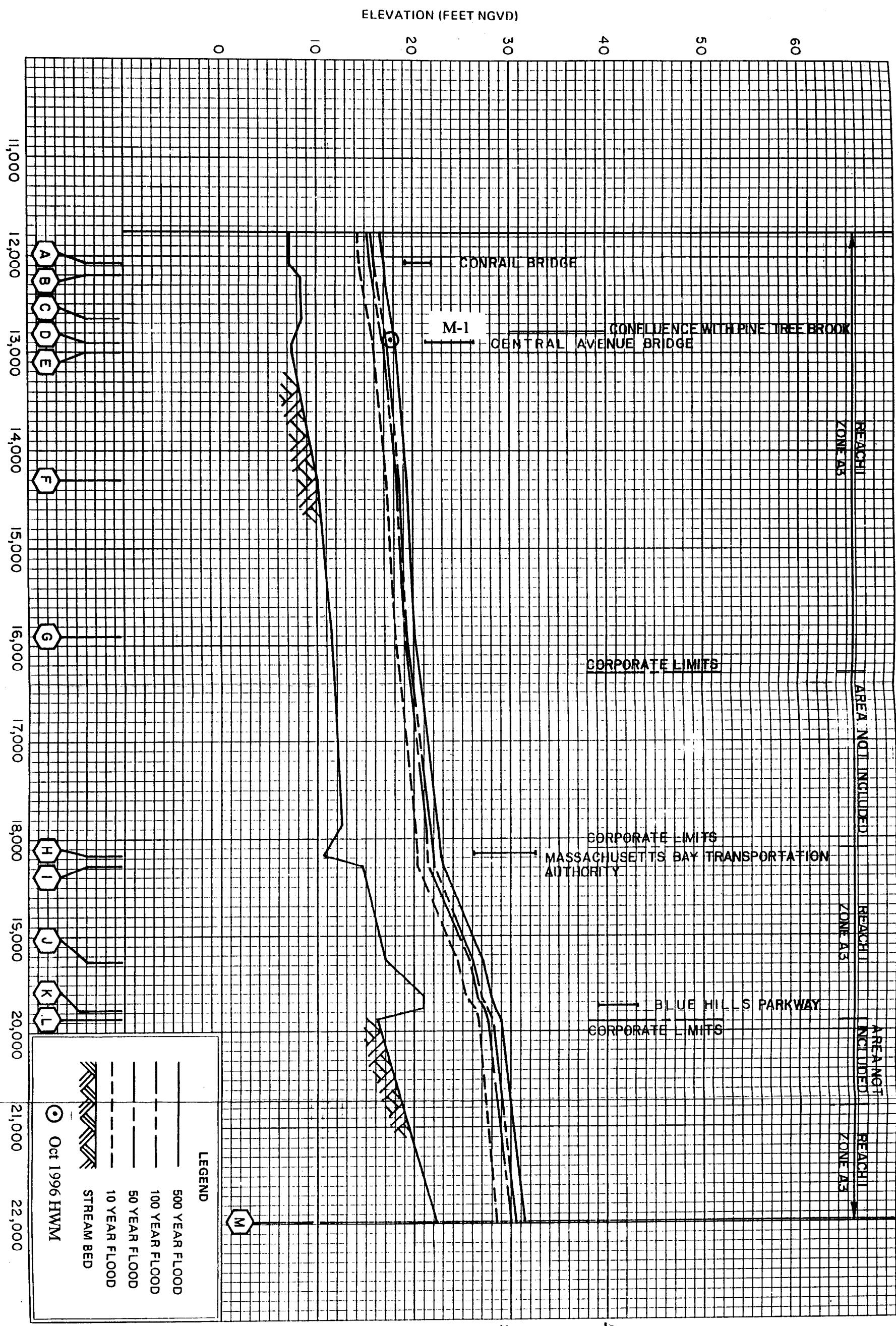


FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF EPPING, NH
(ROCKINGHAM CO.)

FLOOD PROFILES

LAMPREY RIVER



DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

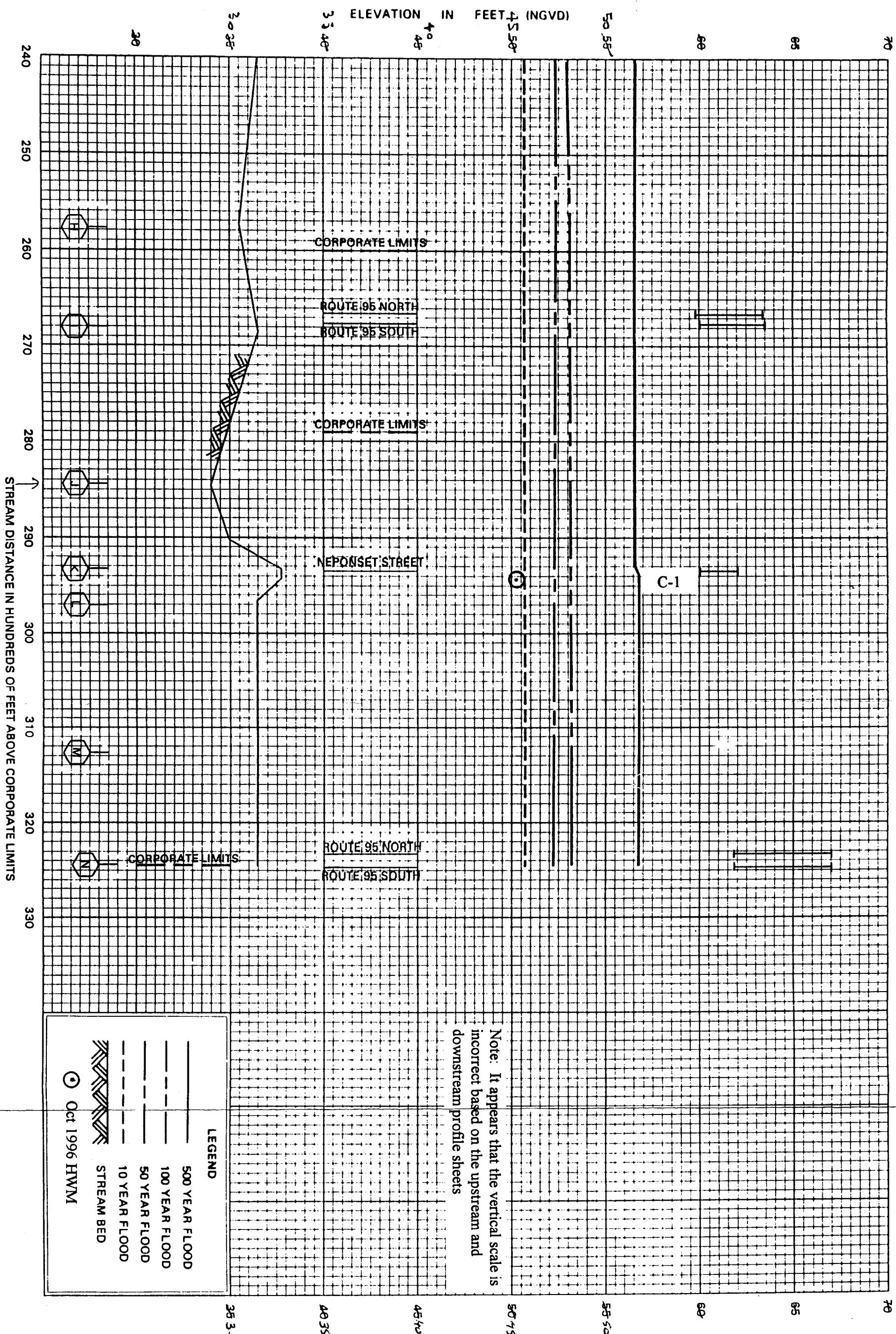
Federal Insurance Administration

TOWN OF MILTON, MA
(NORFOLK CO.)

O 2 P

FLOOD PROFILES

NEPONSET RIVER

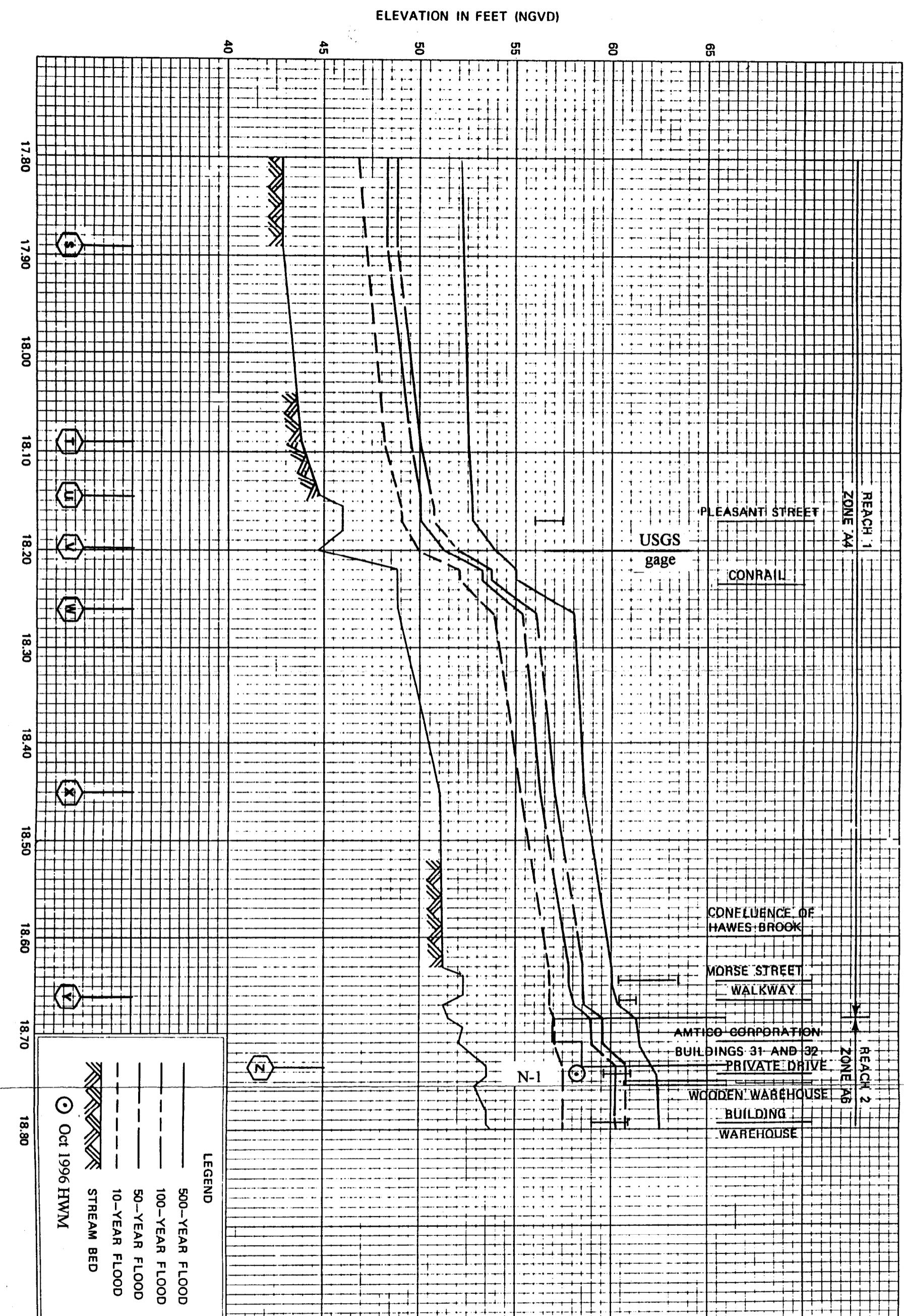


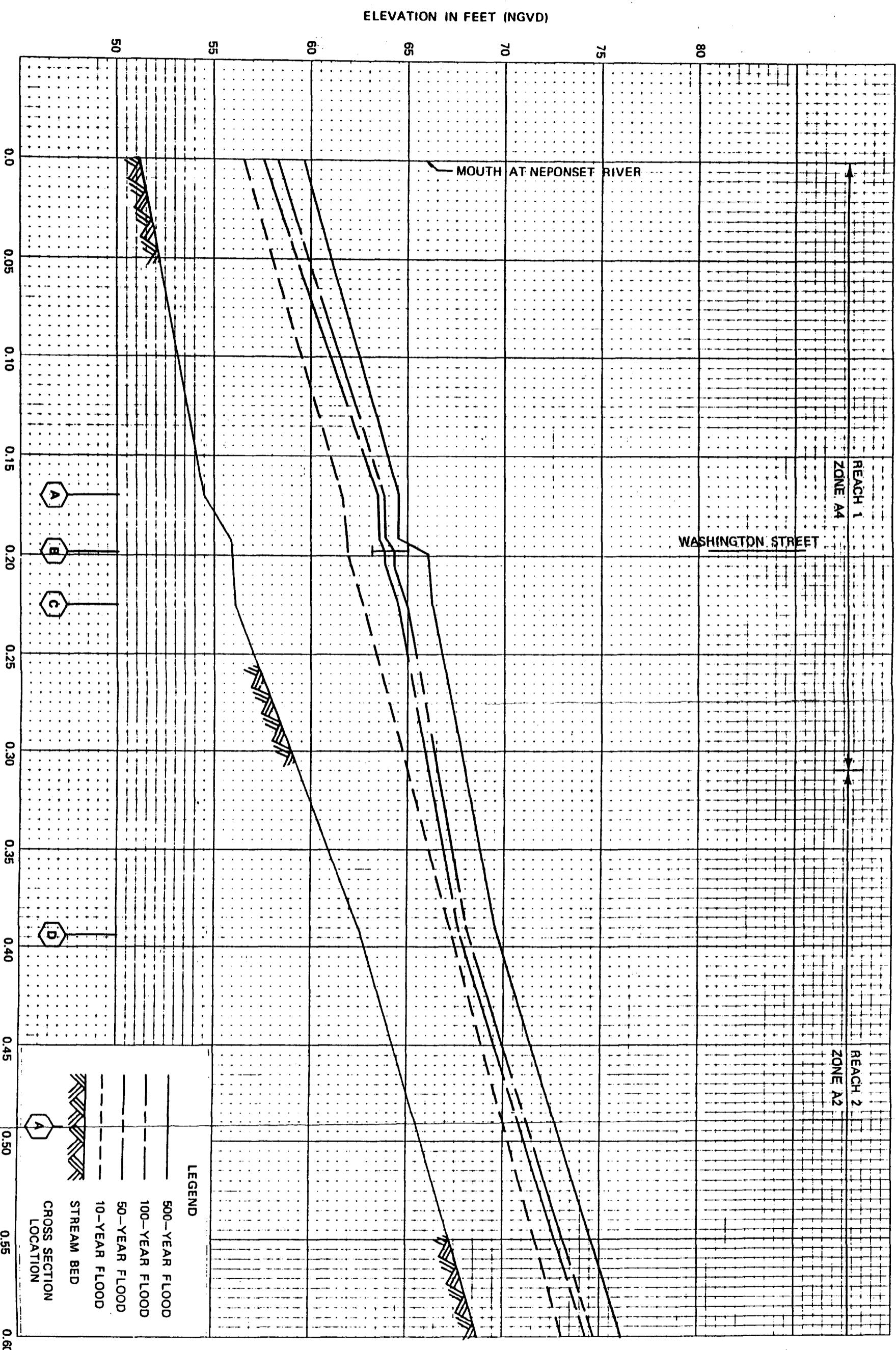
FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF CANTON, MA
(NORFOLK CO.)

FLOOD PROFILES

NEPONSET RIVER

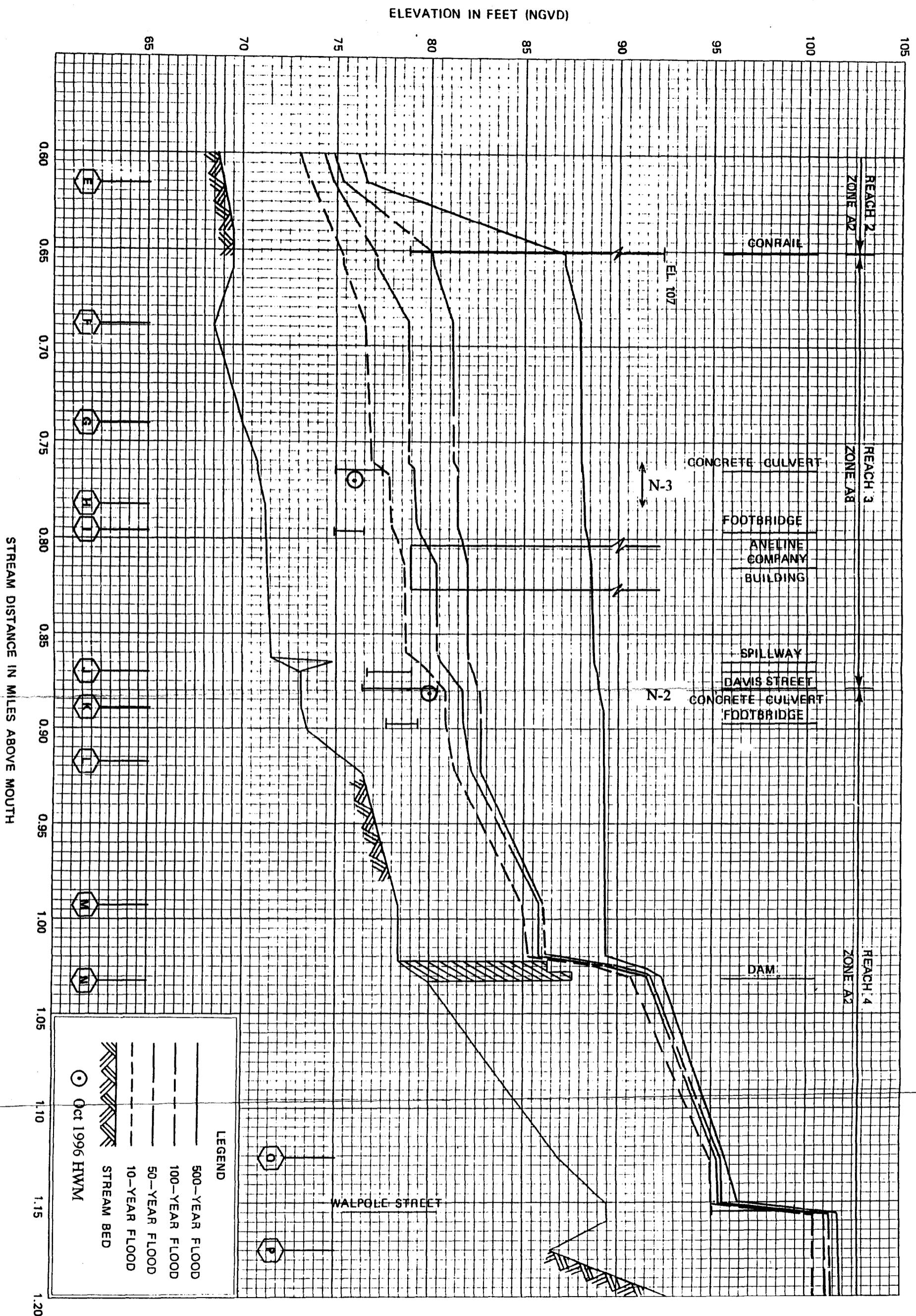




FEDERAL EMERGENCY MANAGEMENT AGENCY
Federal Insurance Administration
TOWN OF NORWOOD, MA
(NORFOLK CO.)

FLOOD PROFILES

HAWES BROOK



FEDERAL EMERGENCY MANAGEMENT AGENCY

Federal Insurance Administration

TOWN OF NORWOOD, MA
(NORFOLK CO.)

FLOOD PROFILES

HAWES BROOK